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7/25/68

# DIGITAL SIMULATION MODELS OF FOREST INVESTMENT AND MANAGEMENT

A THESIS

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# SUMMARY

A significant problem confronting the southern pulp and paper industry is decision making in the area of long-term forest management. In particular, the forest must be considered a renewable resource which must be managed in an economical and effective manner.

The objective of this thesis is the development of a technique whereby the individual pulp-producing company can evaluate the level of forest management required to support a continuing demand for pulp from a limited company controlled forest resource. To achieve this goal, separate but related digital simulation models are developed for forest investment and management.

The forest investment model is constructed in the "DYNAMO" computer language. The model is used to evaluate the relative profitability of different forest management treatments on different types of land using rate-of-return on investment as the measure of effectiveness.

Multiple runs of the forest investment model are used in determining a unique cutting sequence for an exhaustive set of different types of land. The sequence is based on a regret function involving incremental changes in rate-of-return.

The concept of the unique cutting sequence is used in developing a large-scale simulation model of a heterogeneous forest resource. Constructed in the "ALGOL" language, the forest management model simulates the dynamic behavior of the forest resource as affected by growth, forest management policies, and harvesting decisions. The model

incorporates the dual objectives of demand satisfaction and profitable investment.

The models are general in nature and allow experimentation with differing sets of parameters, coefficients, and policies. Numerical results are of course dependent on input parameters. Although no policies of optimal forest management are evident from this study, the models are representative of the real-world forest management environment and can be used as a decision making tool by the company engaged in forest resource management.

# CHAPTER I

# INTRODUCTION

## Nature of the Problem

During the past several decades there have been significant increases in the national demand for paper and other woodpulp-based products. In 1964 Chidester (1) reported that the annual per capita consumption of paper and paperboard was 450 pounds--more than five times that of 1920. He further predicted that the demand for woodpulp-based products could well triple by the year 2000. Beggs (2) pointed out that in 1964 the nation's pulp mills consumed some 49,000,000 cords of wood and predicted that by 1975 over 77,000,000 cords per year will be required.

Likewise, over this same period of time, the pulpwood industry in the South has shown exceptional growth. In 1920, there were 24 pulpmills operating in the South with an average mill production capacity of 41 tons of pulp per day (3). In 1964, 82 mills were in operation and average mill capacity had increased to approximately 690 tons per day (4). Even more significant, in 1920, the South's share of the national market was only 6 per cent; but in 1961 the capacity of southern mills represented 57 per cent of the total national production capacity (5).

Thus it can be concluded that while the South is currently accomplishing a large-scale task of producing and collecting wood for pulping, the task will grow substantially in the future.

During the past half century of growth in the Southern pulpwood industry, however, the system of procuring and transporting wood to the mill has changed little. Around 1920, the pulp companies adopted the practice of appointing local merchants as wood buyers. These merchants bought wood from a large number of small independent producers and transported it to the mill. Although this system has been modified to some degree over the years, essentially the same wood procurement system exists today. In 1961, Britt (6) estimated that 88 per cent of all pulpwood procurement in the United States was harvested by independent producers and that 63 per cent was routed to the mill through a dealer. In the South, the producer dealer system predominates to an even greater degree.

Under the dealership system, which was described by Busch (7) as ". . . a practical method to keep up with the many small transactions necessary to accumulate millions of cords of pulpwood each year," Southern pulp mills have experienced numerous problems with wood flow and wood shortages. Shortages of major proportions occurred in 1955 and 1959 and less acute more localized shortages have occurred at other times. It is the very nature of the procurement system which has contributed to these shortages. The independent producers have simply not been able to keep up with the increases in demand required to support the Southern mills.

For the most part, pulpwood harvesting is only a part-time occupation for the independent producers. Many small farmer-landowners harvest pulpwood only during the winter months when they are not engaged with farming activities. In addition, those producers that harvest pulpwood on a full-time basis generally operate on a small scale, often employing only one crew and the simplest of harvesting techniques and equipment.

Of significant importance to the pulpwood industry has been the impact of mechanization. Silversides (8) described this relationship in detail. A labor intensive operation (as exists in the producer-dealer system) is very flexible, although relatively inefficient. Labor costs make up the largest part of the total cost and changes in total productivity can be regulated by changing the size of the work force. In a highly mechanized operation, however, total cost is predominantly made up of the cost of capital equipment. The result is a rigidity in cost per unit related to the capacity of the mechanized system. As efficiency and productivity are stressed, the degree of mechanization is increased. Likewise, as capital investments are increased, there is a trend towards maximum utilization. It is here that the weakness of the producer-dealer system is evident. Mechanized equipment has been developed during the past two decades that is capable of significantly improving the productivity of the harvesting operation. However, due to the large investment required and the small scale of their operations, the independent producers of pulpwood are incapable of mechanization to any great degree. Investment in mechanization generally involves the purchase of numerous pieces of equipment such as harvesters, skidders and trucks in order to balance the productivity of the system. Such a quantum jump in investment is often prohibitive for the independent producer and represents a risk which most producers are unwilling to take. The importance of the mechanization concept was pointed out in a study of the Southern pulpwood procurement system by Hamilton (9). The primary recommendation of this study was that the hauling function be removed from the producer and assigned to hauling specialists. Because of their size, the hauling specialists would be better able to add trucks (increase capacity). Likewise, the producers could concentrate their capital on improved harvesting equipment.

Another major problem confronting the Southern pulp and paper industry is that of land productivity. The U. S. Forest Service (10) investigated the productivity of privately-owned forest land by ranking recently cut timber land into three productivity classes. Results showed that the South had the lowest percentage of its forest land in the upper productivity class and the highest percentage in the lowest productivity class for every size of forest ownership. The difference in productivity between industrially- and privately-owned land is shown in Table 1 for the period 1956 through 1966.

Table 1. Land Productivity in the South

| Year | Individual Ownership (Cords per Acre) | Company Ownership (Cords per Acre) |
|---|---|---|
| 1956 | 0.092 | 0.209 |
| 1958 | 0.087 | 0.170 |
| 1960 | 0.095 | 0.194 |
| 1962 | 0.097 | 0.219 |
| 1964 | 0.103 | 0.248 |
| 1966 | 0.119 | 0.253 |

Source: Southern Pulpwood Conservation Association, *Economic Analysis of the Southern Pulp and Paper Industry*.

Values were obtained by dividing production of pulpwood by total acreage in the two cases. Company-owned land is shown to have a significant advantage over individually-owned land in terms of productivity per acre.

Landsberg (11) pointed out some of the reasons why the productivity of so much of the forest land in the South is so far below that found on better managed lands of similar forest type. Basically, independent non-industrial forest owners are a heterogeneous group with many reasons inhibiting their practice of forestry. Included are such reasons as lack of assets, lack of knowledge of forestry economics, and the small magnitude of returns from the generally small forest properties held by the independent owner.

Due to the advantages of large-scale mechanized harvesting operations, the increased productivity of company-owned land, and the problems that have been experienced with the producer-dealer procurement system, companies in the pulp and paper industry have commenced an intensive program of land acquisition. Companies operating in the South have benefited greatly from the vast timber reserves in that part of the country. About 630 million acres in the U. S. now grow trees and nearly three-fourths of this forest land is capable of producing commercial timber. The South, with some 201 million acres, possesses approximately 45 per cent of the nation's commercial forestland.

The extent of the pulp and paper companies' efforts toward land ownership can be seen from the trends in land ownership structure. Commercial forest land can be divided into two main categories according to type of ownership: industrial and non-industrial. Non-industrial forest ownership includes all privately- and publicly-owned commercial forest properties not associated with wood manufacturing firms. During past years, changes in ownership have been substantial but have nearly balanced one another with the total acreage almost constant. Industrial ownership has increased, with a decline in lumber companies' ownership and an increase in land held or controlled under lease by pulp and paper companies (12). Table 2 shows the trend in land acquisition during the period 1956 to 1966. The increase in land ownership by pulp and paper companies has been equal to 6.414 per cent for every two-year period during the last decade (12).

Table 2. Land Acquisition by Pulp and Paper Companies

| Year | Acres of Pulp and Paper Company Forests | Per Cent Increase |
|---|---|---|
| 1956 | 18,492,400 | ** |
| 1958 | 20,385,600 | 10.24 |
| 1960 | 21,809,600 | 6.98 |
| 1962 | 21,888,500 | .36 |
| 1964 | 23,058,500 | 5.34 |
| 1966 | 25,169,300 | 9.15 |

Source: Southern Pulpwood Conservation Association, *Economic Analysis of the Southern Pulp and Paper Industry.*

The growing of forests and the kind of forest management required to maintain forest productivity are long-term activities that require programs and investments that may not show significant returns for many decades. Investment in land and standing timber, together with expenses for fire and disease protection, taxes, management expenses, and interest charges results in a significant capital outlay, especially when the amount of land is large.

The fact that large areas are needed for profitable forestry, and the possibility of shifting much of the necessary return from the wood operation to the processing operation, provides substantial advantages to large-scale company ownership of land. Under company ownership and direction, the pulpwood procurement activity can be significantly improved to provide a more steady flow of wood to the mill. In addition, the large scale of company harvesting operations provides the potential for investment in mechanization and a significant reduction in the cost per cord of wood delivered to the mill.

Investment in forestry can be undertaken economically only if the operation is conducted on a large scale and only with a high level of forest management. The pulp and paper company controlling a large forest resource must practice an intensive long-term program of sustained yield management if it is to achieve a satisfactory return on invested capital.

In managing for sustained yield, the individual company is confronted with many alternatives to choose from. In particular, a large-scale forest holding will undoubtedly contain many types of land (as defined by site index). The company must evaluate the profitability of different forest management treatments on different types of land in order to optimize their forest management investment. Also, the amount of the forest resource required and the productivity of different forest management policies must be balanced against the long-term projection of demand for wood. In the long run, it is desired to minimize investment in land and forest management while still meeting the annual demand for wood. It is the problem of decision making in long-term sustained-yield forest management to which this research is directed.

## Statement of Objectives

The general objective of this research is the development of a technique whereby the individual pulp-producing company can evaluate the level of forest management required to support a continuing demand for pulp from a limited company-controlled forest resource. Specific objectives are as follows:

(1) Development of a general forest investment model capable of evaluating the relative profitability of different forest management treatments on different types of land. Such a model will consider the relevant costs and revenues associated with a complete cycle of timber growth and harvesting. Rate of return on investment will be used as the primary measure of profitability.

(2) Development of a general forest management model to simulate the long-term behavior of a heterogeneous forest resource. Harvesting decisions in the model are to be based on a cutting sequence as determined by profitability considerations. The model is to simulate the dynamic behavior of the forest as affected by growth, forest management policies, and harvesting decisions.

(3) Experimentation with the forest management model under different demand patterns to determine relationships between forest management decisions and the long-term capability of the forest resource to meet a continuing demand for pulp.

## Literature Survey

The field of long-term sustained yield forest management is relatively new and no compact body of knowledge exists that completely describes the state-of-the-art. Techniques and concepts that have been developed to date have been drawn from the ideas of several interrelated disciplines such as heuristic-oriented mathematics, general system theory, operations research, systems analysis, resource system modeling, forest economics, and computer simulation theory. The approach taken in this literature survey was to investigate both the tools and techniques that have been applied in forest management and the significant research effects that have been directed towards improving forest management concepts and methodologies.

The nature and significance of current developments in forest management is described by Hall (13). In his introduction, Hall states: "Management science is catching up with the needs of the executive who forms policy about large holdings of forest land." This is considered a significant development since the wood-using industries historically have not considered themselves experimenters with new business methods. Management science is beginning to assist forest managers with such problems as the following:

(1) Whether or not to buy more forested land?

(2) How much can be paid for it?

(3) How much can be invested each year in planting or other silvicultural practices?

(4) What inventory of standing timber should be carried?

(5) How should blocks of land be scheduled for harvest and regeneration?

Hall emphasizes the systems concept in forest management and states:

> No longer is concern solely with manipulation of land tracts, soil productivity, distribution of tree sizes and volumes, measurement methods, and maximizing production from the ecological community which is the forest. Now the managers must develop entire organizations of people, land, trees, markets, and financial resources into smoothly functioning units . . .

In discussing specific techniques in forest management, Hall emphasizes simulation as the technique with the greatest potential for immediately usable answers to operating questions. Simulation has been particularly useful in realistically scheduling cutting and replanting operations on a large managed forest. By varying cutting policies and schedules, one can arrive at the schedule which comes closest to meeting restrictions of demand, maximum growth, minimum wood cost, etc. The technique has been demonstrated by the FOPS program at the University of Georgia (14), and by Gould and O'Reagan (15,16).

It must be remembered, as Hall points out, that simulation is not a panacea for all business problems. Models do not provide decisions; they only test the outcomes of decisions under broad assumptions and predictions. Even then, a simulation model can test only a small percentage of the infinite combinations of factors that may be present in the real-world system.

Chappelle (17) also stresses the importance of modeling in forestry research and points out that the activity of model building for diagnostic studies of forest management is still in the early stages of development. Chappelle emphasizes the relative lack of dynamic models in forestry economics. The most common type of model used in forestry research is the comparative static model. Although dynamic models are often considered the ultimate aim, their development has not measured up to expectations because of both theoretical and computational difficulties.

The traditional forest regulation model is reviewed and critiqued in detail by Thompson (18). As originally conceptualized, the model consists of a forest composed of even-aged, fully-stocked lands, with one age class for each year of the rotation. In addition, each age class is represented by an area of equal productivity. The probable reason for development of the model was a need for long-range planning of forest production. Attainment of the model produces, among other things, the following three conditions:

1. "A yearly cut of approximately equal volume."
2. "A yearly cut of about the same age, size, and quality of timber, and hence a yearly income of about the same amount."
3. "A current growth and income obtained from a forest capital no larger than necessary, thus insuring a maximum rate of return upon this capital."

Thompson's main criticism of the model is that conditions commonly associated with attaining the model are incompatible with economic considerations. The forest manager is generally guided by objectives which reflect a basic profit motivation along with managerial or institutional constraints. In this respect, the costs associated with attaining the model may be considerably higher than some alternative approach. For example, regulation of an old-growth forest according to the traditional model could result in lost revenue by delaying the harvest of over-mature timber. In general, the model implies certain physical steps necessary for attainment. These steps are divorced from economic considerations and are generally inconsistent with management needs during the period required to attain the model.

In concluding, Thompson states that, ". . . the traditional model seems to be compatible only with the objective of producing an even distribution of age classes, irrespective of cost . . . however, completely adequate substitutes are not presently available."

At the other extreme, Fedkiw and Yoho (19) have developed what can be considered a regulation model for the stumpage producer willing to assume certainty regarding future yields, costs, and prices, and whose sole management objective is maximization of present net worth. The model is based on the concept of financial maturity; that is, timber harvests are scheduled in accordance with maximizing present net worth. In such a model, annual yield may fluctuate quite widely.

An alternate technique of forest management is presented by Bentley and Kaiser (20). This technique employs the use of decision trees and is based on the significance of sequential decisions in the forest management cycle. A timber management decision made at any one point in time may have significant bearing on the possible alternatives in a later decision. Also, chance events, such as mortality, are significant in the decision sequence since probabilities of occurrence are affected by the decisions made. As such, a decision tree can be used to study the relationship over time of production decisions, chance events, and value outcomes. The authors describe the approach as "a practical technique which integrates technical information, economic analysis, expert opinion, and managerial judgment." With appropriate data on costs and returns, the expected outcomes of alternative decision sequences can be ranked in economic terms. Through sensitivity analysis, it is possible to identify and determine the importance of key decision factors.

The authors point out that the decision tree is more complex than the rules of thumb commonly used, but need only be as complex as the decision problem at hand. However, sophisticated models can be developed which relate a large number of decisions and incorporate complex probability distributions for chance events. A case study of Christmas tree production is presented as an example of the application and usefulness of the technique.

A significant class of techniques of proven usefulness in forest management decision making is mathematical programming. The most highly developed single method to date is linear programming, although introductory studies have been made using integer, quadratic, convex, and dynamic programming. Scheduling of cutting, planting, and other silvicultural applications seems to be the major area of potential application. Several companies are using linear programming models to associate known product potentialities of standing timber with anticipated short-term demand, in order to shift cutting to meet the demand most efficiently (13).

Curtis (21) presents an excellent introductory treatment of the nature of linear programming and its applicability to forest management.

The author supplements his discussion with an example of the application of linear programming to a particular forest management problem at the Buckeye Cellulose Corporation.

Two linear programming models designed to aid in developing sustained yield cutting schedules are presented by Loucks (22). In the first model the volume to be cut is maximized subject to the various conditions imposed by nature and required by the management plan. In the second model, the area to be cut is minimized while assuring a specified yield for each cutting period. Various management alternatives are considered and evaluated in terms of the effect on the total yield produced.

Additional examples of linear programming applications are presented by Kidd, et al. (23) and Liittschwager and Tcheng (24). The Liittschwager and Tcheng application is particularly interesting in that it involves the use of the decomposition principle in solving a very large-scale problem as would be experienced in a real-world application.

Although linear programming is in widespread use in forest management, there are numerous difficulties and limitations associated with its application. The model treats all variables as linear and continuous. Thus, although the model can schedule a number of acres to be treated silviculturally or cut, it does not allocate which particular tracts are to be involved. Also, the technique is limited in the time dimension, permitting planning only for a restricted number of time periods. In addition, the model prohibits variation in treatments and sequence in the second and subsequent rotations.

A major obstacle to the application of linear programming lies in setting up a realistic schedule of periodic yields per acre for each stand in the analysis. The volume per acre to be cut--or the expected yield--during each cutting period will depend on expected growth. Expected growth, in turn, will depend upon cutting intensity and distribution of cut. The general equation relating yield, growth, and cut is as follows:

residual volume = initial volume + growth - cut

Since volume cut or acreage cut is usually the decision variable, it is therefore impossible to determine a realistic yield schedule to use in the analysis until after the analysis is complete. As such, the yield schedule adopted is a very significant simplifying assumption.

One area of forest management which has been developed to a fairly high degree is the use of discounted cash flow in evaluating capital investments. Internal rate of return is considered by many to be the most readily usable criterion of analysis and numerous pulp and paper companies use it for evaluating purchases of land and investment in silvicultural treatments. An example of a general computer model for the calculation of rates-of-return for complex forest investment alternatives is presented by Row (25). The model will evaluate six investment alternatives simultaneously and perform the analysis repetitively for many cost and price situations.

The gravity of the entire forest management problem is best summarized by Swan (26). Swan describes forestland as a ". . . vast renewable natural resource . . ." capable of ensuring a permanent forest crop. However, he points out that ". . . no one has invented instant trees yet . . ." and that it is difficult to motivate forest managers ". . . who seldom attempt to look ahead as much as 10 years, to start looking ahead for periods that are meaningful in terms of forest management . . ."

Swan identifies two alternatives to the forest management problem: ". . . intensify forest practice so existing and future mills can be supplied in perpetuity with wood they can afford to use, or revert to a policy of simply accepting steadily rising wood costs until the operation becomes uneconomic." In this respect, the outlook of forest managers must decidedly be long term.

At present the technique and methodologies associated with forest management are in a state of rapid advancement and development. Research is progressing on numerous approaches to the problems of forest systems management. Also, numerous applications to real-world systems have been made. However, to date, no encompassing theory of forest management has been developed.

## Investigating Procedure

This research was carried out in a series of fairly distinct steps as outlined below:

(1) Problem identification and literature survey.

(2) Construction of the Forest Investment Model.

(3) Experimentation with the Forest Investment Model.

(4) Development of a cutting sequence based on rate of return considerations.

(5) Construction of the Forest Management Model.

(6) Experimentation with the Forest Management Model under different demand patterns.

(7) Analysis of results and consideration of real-world implications.

Data Sources

The data used in establishing the parameters in the models were obtained primarily through literature searches. Data values included in the models are considered to be "representative" of the real-world situation. The models are constructed in a general format and it is assumed that application of either or both of the models would involve the inclusion of accurate data representative of the particular situation being studied.

# CHAPTER II

# THE FOREST INVESTMENT MODEL

The forest investment model is written in the DYNAMO computer language. It is assumed that the reader has a basic understanding of this language as presented by Pugh (27). It should be noted that although the DYNAMO language was developed in conjunction with Jay W. Forrester's Industrial Dynamics studies at the Massachusetts Institute of Technology, the forest investment model is not formulated in the Industrial Dynamics philosophy. Rather, the DYNAMO language is used solely for its computational efficiency and capability for graphical output.

## General Description

The forest investment model is designed to evaluate the relative profitability of different forest management treatments on different types of land as defined by site index. The model is concerned with the individual acre of land and the costs and revenues associated with one complete cycle of timber growth and harvesting.

The primary variables in the model are:

(1) Land cost

(2) Site preparation and planting cost

(3) Stumpage price

(4) Land taxes

(5) Forest management costs

(6) Yield

(7) Investment rate for idle capital

(8) Inflation rate

The model sequence commences at YEAR=0 with the planting of an acre of land. Land value, site preparation and planting cost, stumpage price, land tax rate, and forest management cost are input to the model as constant values at YEAR=0.

As the model progresses, all expenses are converted to current value (planting time) and recorded as initial investment. Current values of land value, stumpage price, taxes and management costs are computed each year to include the effects of inflation. At each year, the rate of return is computed based on the total value of assets at that time as compared with the initial value of all expenditures. Output of the model is a plot of rate of return on investment as a function of time.

## Model Formulation

The model is structured as a closed loop system having a simple input drive and one primary output variable. A flow diagram of the entire model is shown in Figure 1.

The input drive to the model is nothing more than a set of time-keeping equations. These equations keep track of the age of the wood and cause all operational equations to be executed for every value of age.

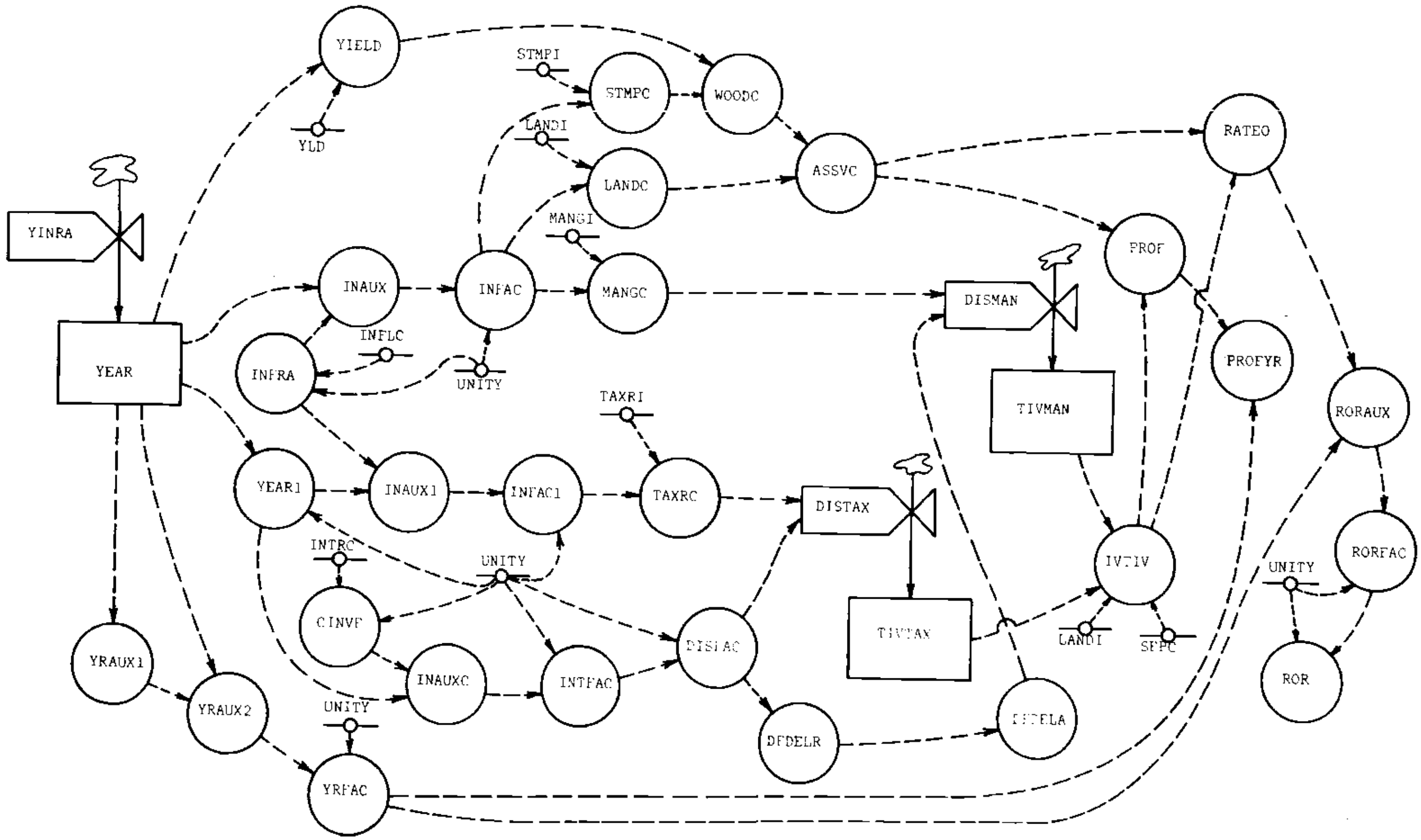


Figure 1. Flow Diagram of the Forest Investment Model

IL* YEAR.K=YEAR.J+(DT)(YINRA+0)
6N YEAR=0
C YINRA=1

YEAR - Current Year
DT - Solution Time Interval (Years)
YINRA - Yearly Increment Rate (1)

In order to take the effect of inflation into account, DYNAMO must compute an inflation factor of the following form:

$$INFAC=(1+INFLC)^{N}$$

INFAC - Inflation Factor
INFLC - Inflation Constant
N - Current Value of Years

DYNAMO must execute this computation using logarithms. The mathematical sequence of operations is as follows:

$$INFAC=(1+INFLC)^{N}$$

$$\ln(INFAC)=N\ln(1+INFLC)$$

evaluating

$$N\ln(1+INFLC)=INAUX$$

leaves

$$\ln(INFAC)=INAUX$$

converting to exponential form;

$$INFAC=e^{INAUX}$$

evaluating

$$e^{INAUX}$$

gives a numerical value for INFAC.

---

*The numeric value denotes the *form* of the DYNAMO equation. The alphabetic designator denotes the type of DYNAMO equation. Note that N designates an initial condition for the variable described and C denotes a constant value.

The DYNAMO equations required to perform this computation are as follows:

```
7A     INFRA.K=UNITY+INFLC
C      UNITY=1.0
C      INFLC=.035
29A    INAUX.K=(YEAR.K)LOGN(INFRA.K)
28A    INFAC.K=(UNITY)EXP(INAUX.K)
```

INFRA - Inflation Rate (Per Cent)
UNITY - Constant of One (Dimensionless)
INFLC - Inflation Constant (Per Cent)
INAUX - Auxiliary Needed to Compute Inflation Factor for Current Year (Dimensionless)
YEAR - Current Year
INFAC - Inflation Factor for the Current Year (Dimensionless)

The current value (at Year N) of land value, stumpage price and the annual forest management cost is formulated as a function of initial values and the Inflation Factor.

```
12A    STMPC.K=(INFAC.K)(STMPI)
C      STMPI=7.50
12A    LANDC.K=(INFAC.K)(LANDI)
C      LANDI="A constant value dependent on
       the site index of the land under
       consideration."
12A    MANGC.K=(INFAC.K)(MANGI)
C      MANGI="A constant value dependent on
       whether the land under consideration is
       in plantation or natural status."
```

STMPC - Current Stumpage Price (Dollars/Cord)
INFAC - Inflation Factor for the Current Year (Dimensionless)
STMPI - Initial Stumpage Price (Dollars/Cord)
LANDC - Current Land Value (Dollars/Acre)
LANDI - Initial Land Value (Dollars/Acre)
MANGC - Current Land Management Cost (Dollars/Acre)
MANGI - Initial Land Management Cost (Dollars/Acre)

The current value of assets is the sum of the current land value plus the current wood value. The current wood value is a function of the current stumpage value and the value of yield. In this study, yield was taken as a table of coefficients representing potential cords cut if the land were cut in year N where N was taken from zero to 50.

```
7A     ASSVC.K=LANDC.K+WOODC.K
72A    WOODC.K=(YIELD.K)(STMPC.K)
59A    YIELD.K=TABLE(YLD,YEAR.K,0,50,1)
C      YLD*="A set of 51 coefficients reflecting
       potential yield in years 0-50."
```

ASSVC - Current Value of Assets (Dollars/Acre)
LANDC - Current Land Value (Dollars/Acre)
WOODC - Current Wood Value (Dollars/Acre)
YIELD - Yield of Land (Cords/Acre)
STMPC - Current Stumpage Price (Dollars/Cord)
YLD - Yield Table (Cords/Acre)
YEAR - Current Year

Since land taxes are not payable until the end of the year, another inflation factor of the form:

$$INFAC1=(1+INFRA)^{N+1}$$

is required. Again using logarithms, the necessary DYNAMO equations are as follows:

```
7A     YEAR1.K=YEAR.K+UNITY
29A    INAUX1.K=(YEAR1.K)LOGN(INFRA.K)
28A    INFAC1.K=(UNITY)EXP(INAUX1.K)
```

YEAR1 - Current Year Plus One
YEAR - Current Year
UNITY - Constant of One (Dimensionless)
INAUX1 - Auxiliary Needed to Compute Inflation Factor for Current Year Plus One (Dimensionless)
INFRA - Inflation Rate (Per Cent)
INFAC1 - Inflation Factor for Current Year Plus One (Dimensionless)

The current value of annual taxes is then formulated as a function of the initial tax rate and the Inflation Factor.

```
12A    TAXRC.K=(INFAC1.K)(TAXRI)
C      TAXRI=1.00
```

TAXRC - Current Tax Rate (Dollars/Acre)
INFAC1 - Inflation Factor for Current Year Plus One (Dimensionless)
TAXRI - Initial Tax Rate (Dollars/Acre)

Working capital is assumed to be invested until actually required. Thus a discount factor is required to determine the initial amount of working capital required to meet an expense at the end of year N.

```
7A    CINVF.K=UNITY+INTRC
C     INTRC=.07
29A   INAUXC.K=(YEAR1.K)LOGN(CINVF.K)
28A   INTFAC.K=(UNITY)EXP(INAUXC.K)
20A   DISFAC.K=UNITY/INTFAC.K
```

CINVF - Capital Investment Factor (Per Cent)
UNITY - Constant of One (Dimensionless)
INTRC - Interest Rate for Idle Capital (Per Cent)
INAUXC - Auxiliary Needed to Compute Interest Factor for Idle Capital (Dimensionless)
YEAR1 - Current Year Plus One
INTFAC - Interest Factor for Current Year (Dimensionless)
DISFAC - Discount Factor for Current Capital (Dimensionless)

The total initial value of taxes paid is the sum of the discounted value of all annual taxes paid through the end of the current year. Note that next year's taxes must be discounted in advance in order that they be included in the summation one year hence.

```
IL    TIVTAX.K=TIVTAX.J+(DT)(DISTAX.JK+0)
6N    TIVTAX=0
12R   DISTAX.KL=(DISFAC.K)(TAXRC.K)
```

TIVTAX - Total Initial Value of Taxes Paid Through End of Current Year (Dollars/Acre)
DT - Solution Time Interval (Years)
DISTAX - Discounted Value of Next Years Taxes (Dollars/Acre)
DISFAC - Discount Factor for Current Capital (Dimensionless)
TAXRC - Current Tax Rate (Dollars/Acre)

Land management cost is assumed to be incurred in the beginning of the year in which it applies. Consequently, the discounted value of land management cost must be computed on the basis of the value of Current Year (YEAR) rather than on Current Year Plus One (YEAR1) as was the expense for taxes. This can be accomplished by delaying for one year the discount factor (DISFAC) already computed. The equations required to accomplish this delay are as follows:

```
6R    DFDELR.KL=DISFAC.K
6A    DFDELA.K=DFDELR.JK
6N    DFDELA=1.00
```

DFDELR - Discount Factor Delay Rate (Dimensionless)
DISFAC - Discount Factor for Current Capital (Dimensionless)
DFDELA - Discount Factor Delay Auxiliary (Dimensionless)

The total initial value of all land management costs is the sum of the discounted value (using the delayed discount factor) of all annual land management costs through the end of the current year. Note again that next year's expense must be discounted in advance in order that it be included in the summation one year hence.

```
IL    TIVMAN.K=TIVMAN.J+(DT)(DISMAN.JK+0)
6N    TIVMAN=0
12R   DISMAN.KL=(DFDELA.K)(MANGC.K)
```

TIVMAN - Total Initial Value of Land Management Costs Paid Through End of Current Year (Dollars/Acre)
DT - Solution Time Interval (Years)
DISMAN - Discounted Value of Next Years' Land Management Cost (Dollars/Acre)
DFDELA - Discount Factor Delay Auxiliary (Dimensionless)
MANGC - Current Land Management Cost (Dollars/Acre)

The initial value of the total investment can now be formulated as the sum of the initial land cost, the site preparation and planting cost, the sum of the discounted value of taxes paid to date, and the sum of the discounted value of land management costs to date.

```
9A    IVTIV.K=LANDI+SPPC+TIVTAX.K+TIVMAN.K
C     LANDI="A constant value dependent on the
      site index of the land under consideration."
C     SPPC="A constant value dependent on whether
      the land under consideration is in plantation
      or natural status."
```

IVTIV - Initial Value of Total Investment (Dollars/Acre)
LANDI - Initial Land Cost (Dollars/Acre)
SPPC - Site Preparation and Planting Cost (Dollars/Acre)

TIVTAX - Total Initial Value of Taxes Paid Through End of Current Year (Dollars/Acre)
TIVMAN - Total Initial Value of Land Management Costs Paid Through End of Current Year (Dollars/Acre)

Computation of profit per year and rate of return requires division by the current value of YEAR. Preclusion of division by zero when YEAR = 0 requires the following equations:

```
51A    YRAUX1.K=CLIP(0,1,YEAR.K,1)*
7A     YRAUX2.K=YEAR.K+YRAUX1.K
20A    YRFAC.K=UNITY/YRAUX2.K
```

YRAUX1 - Computational Auxiliary (Dimensionless)
YEAR - Current Year
YRAUX2 - Computational Auxiliary (Dimensionless)
YRFAC - Year Factor - One Dividend by the Current Value of Years
UNITY - Constant of One (Dimensionless)

The value of total profit can now be formulated as the difference between the current value of assets and the initial value of total investment. Profit per year is found by dividing total profits by the current value of Years.

```
7A     PROF.K=ASSVC.K-IVTIV.K
12A    PROFYR.K=(YRFAC.K)(PROF.K)
```

PROF - Total Profit at End of Current Year (Dollars/Acre)
ASSVC - Current Value of Assets (Dollars/Acre)
IVTIV - Initial Value of Total Investment (Dollars/Acre)
PROFYR- Profit per Year (Dollars/Acre)
YRFAC - Year Factor - One Divided by the Current Value of Years.

In order to determine rate of return, DYNAMO must evaluate an expression of the following form.

$$ASSVC=IVTIV(1+ROR)^N$$

---

*A clip function is interpreted in the following manner:

$$YRAUX1.K = \begin{cases} 0 \text{ if } YEAR.K \geq 1 \\ 1 \text{ if } YEAR.K < 1 \end{cases}$$

ASSVC - Current Value of Assets
IVTIV - Initial Value of Total Investment
ROR - Rate of Return on Initial Investment
N - Current Value of YEAR

DYNAMO must execute this computation using logarithms. The mathematical sequence of operations is as follows:

$$ASSVC=IVTIV(1+ROR)^N$$

$$\frac{ASSVC}{IVTIV}=(1+ROR)^N$$

$$\ln(ASSVC/IVTIV)=N\ln(1+ROR)$$

$$\frac{1}{N}\ln(ASSVC/IVTIV)=\ln(1+ROR)$$

Evaluating

$$\frac{1}{N}\ln(ASSVC/IVTIV)=RORAUX$$

leaves

$$\ln(1+ROR)=RORAUX$$

converting to exponential form:

$$1+ROR=e^{RORAUX}$$

evaluating

$$e^{RORAUX}=RORFAC$$

leaves

$$1+ROR=RORFAC$$

or

$$ROR=RORFAC-1$$

The DYNAMO equations required to perform this computation are as follows:

```
20A    RATEO.K=ASSVC.K/IVTIV.K
29A    RORAUX.K=(YRFAC.K)LOGN(RATEO.K)
28A    RORFAC.K=(UNITY)EXP(RORAUX.K)
7A     ROR.K=RORFAC.K-UNITY
```

RATEO - Ratio of Current Value of Assets to Initial Value of Total Investment (Dimensionless)
ASSVC - Current Value of Assets (Dollars/Acre)
IVTIV - Initial Value of Total Investment (Dollars/Acre)
RORAUX - Auxiliary Needed to Compute Rate of Return for Current Year (Dimensionless)
YRFAC - Year Factor - One Divided by the Current Value of Years
RORFAC - Rate of Return Factor for Current Year (Per Cent)
UNITY - Constant of One
ROR - Rate of Return on Initial Investment (Per Cent)

The solution time interval is chosen as DT = 1. The program is run for LENGTH = 50, thus computing rate of return for rotation ages up to 50 years. The specifications PRTPER = 1, and PLTPER = 1, print in tabular form and plot in graphic form the requested quantities with one year spacing intervals. The DYNAMO specifications used in the program are summarized below.

SPEC DT=1/LENGTH=50/PRTPER-1/PLTPER-1

A complete listing of the forest investment model is shown in Appendix A.

# CHAPTER III

# RESULTS OF THE FOREST INVESTMENT MODEL

## General

The forest investment model was purposely constructed in as general a format as possible. As such, the model can be used to test any combination of initial conditions and forest management policy. For the purpose of this study, however, it was desired to limit model experiments to a representative exhaustive set of initial conditions and policy decisions that might confront a particular pulp-producing company. In this manner, all alternatives can be evaluated and ranked according to profitability considerations.

In this study, it was assumed that all forestland under consideration could be categorized in one of five site indices. Those site indices selected were 30, 40, 50, 60, and 70 (25-year basis).

It was further assumed that only two forest management alternatives would be compared. One alternative, designated plantation, implies the planting of seedlings in a regular pattern and a high level of annual forest management. The other alternative, designated natural growth, implies random dispersal of seed from parent trees and a moderate amount of annual forest management. Annual forest management is assumed to consist of weeding, thinning, protection from fire and disease, etc. It should be noted that in this study the term natural growth does not represent a complete reliance on natural phenomena but implies preparation of the seedbed and a moderate amount of annual forest management.

## Parameter Combinations Tested

In considering the relationship between quality of land, forest management policies, and parameter values in the model, the following assumptions were made.

(1) Land cost (LANDI) is to some degree a function of land quality.

(2) Site preparation and planting cost (SPPC) is a function of the management policy.

(3) Land management cost (MANGI) is a function of the management policy.

The impact of other considerations on these costs is acknowledged. However, it was assumed that structured relationships could be established between site index, management policy, and the numerical values of the three costs. These relationships, and the numerical values selected for consideration, are shown in Table 3.

Table 3. Parameter Combinations Tested in the Forest Investment Model

| Run | Index | Policy | LANDI ($/Acre) | SPPEC ($/Acre) | MANGI ($/Acre) |
|---|---|---|---|---|---|
| 1 | 30 | Natural | 50.00 | 30.00 | 1.00 |
| 2 | 30 | Plantation | 50.00 | 40.00 | 1.50 |
| 3 | 40 | Natural | 56.00 | 30.00 | 1.00 |
| 4 | 40 | Plantation | 56.00 | 40.00 | 1.50 |
| 5 | 50 | Natural | 62.00 | 30.00 | 1.00 |
| 6 | 50 | Plantation | 62.00 | 40.00 | 1.50 |
| 7 | 60 | Natural | 68.00 | 30.00 | 1.00 |
| 8 | 60 | Plantation | 68.00 | 40.00 | 1.50 |
| 9 | 70 | Natural | 74.00 | 30.00 | 1.00 |
| 10 | 70 | Plantation | 74.00 | 40.00 | 1.50 |

In all runs, the inflation constant (INFLC), the interest rate for idle capital (INTRC), the initial stumpage price (STMPI), and the initial tax rate (TAXRI) were held at the following constant values.

| | |
|---|---|
| INFLC=.035 | (Per Cent) |
| INTRC=.07 | (Per Cent) |
| STMPI=7.50 | (Dollars/Acre) |
| TAXRI=1.00 | (Dollars/Acre) |

The value of yield expressed in cords of merchantable wood per acre is dependent upon the species of tree, the site index of the land, the management policy, and the age of the stand. It was assumed in this study that all stands are of even aged slash pine. Representative yield coefficients were obtained from the works of Langdon (28) and Bennett (29). The relationship between yield, age and site index is displayed in Figures 2 and 3 for natural and plantation land, respectively. Tabular values of yield coefficients used in the model experiments are shown in Table 4.

## Results

The graphical output for the ten runs is shown in Figures 4 through 13. In all figures, the time scale goes from 0 to 50 (YEARS). Each of the three variables is plotted on a different scale as shown below.

| Variable | Symbol | Scale | Units |
|---|---|---|---|
| Rate of Return | R | -.05 to .15 | Per Cent |
| Profit | P | 0 to 5000 | Dollars/Acre |
| Profit per Year | Y | 0 to 100 | Dollars/Acre/Year |

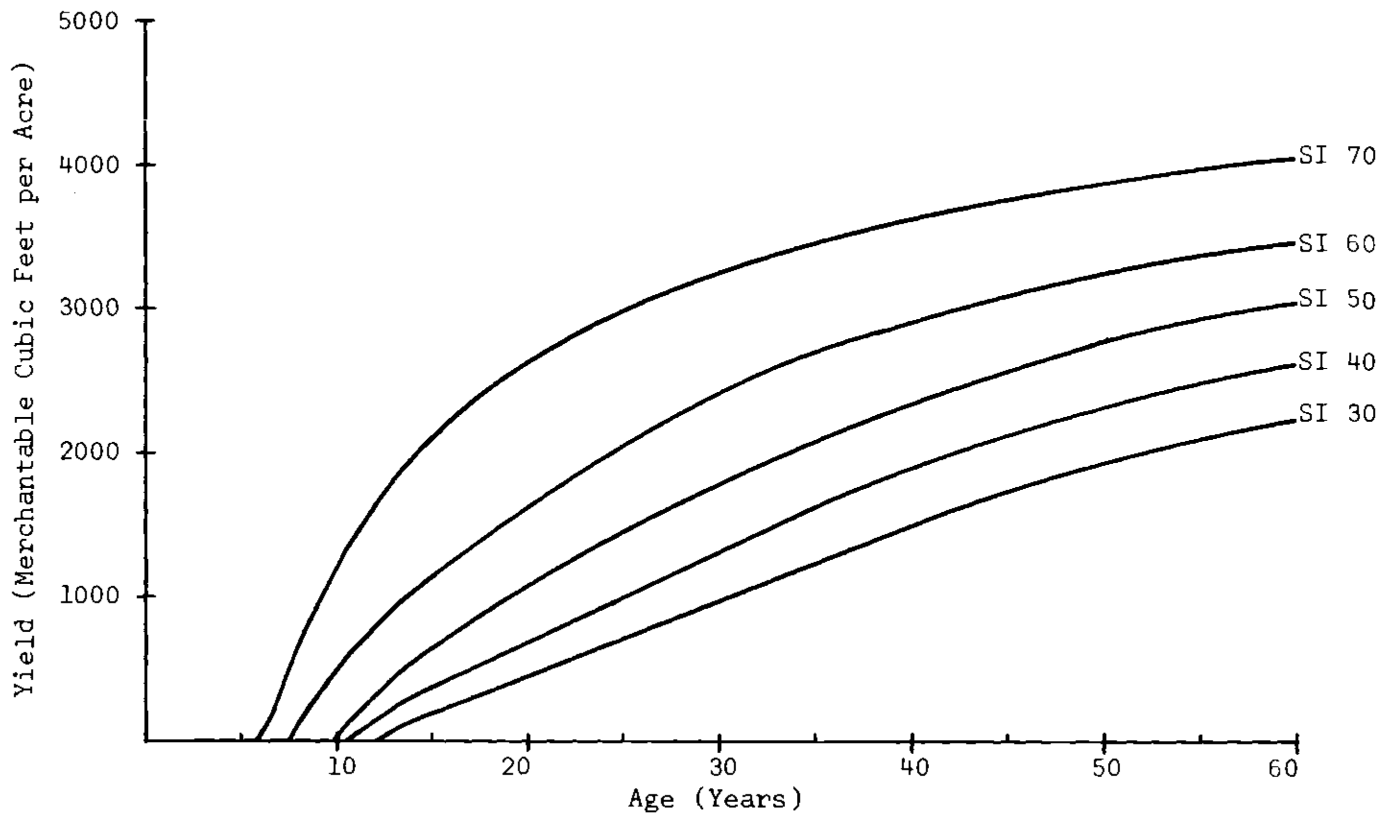


Figure 2. Yield from Natural Stands of Slash Pine (Merchantable Wood) Source: Langdon, O. Gordon, *Yield of Unmanaged Slash Pine Stands in South Florida,* U.S. Department of Agriculture-Forest Service, Southeastern Forest Experiment Station, Station Paper No. 123, June, 1961.

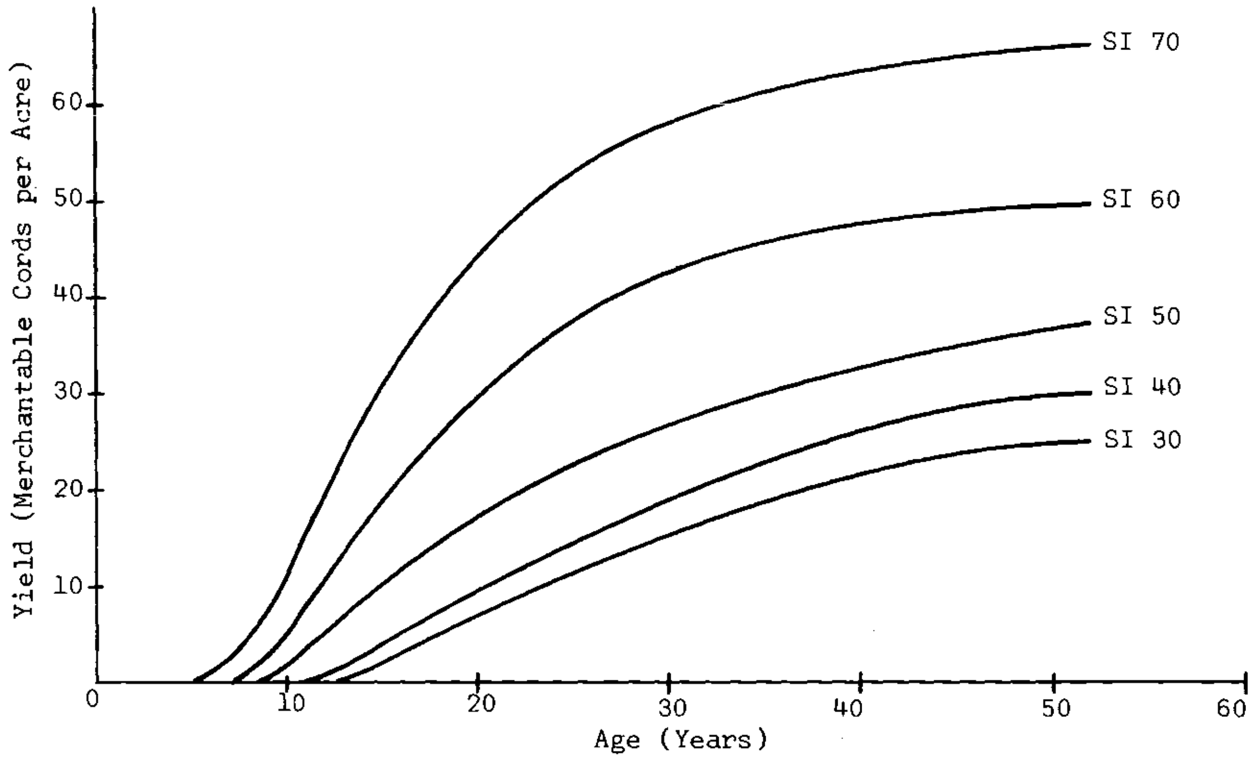


Figure 3. Yield of Slash Pine Plantations (Merchantable Wood). Based on 6'×6' Initial Spacing. Source: Bennett, Frank A., *Growth and Yield of Slash Pine Plantations*, U. S. Department of Agriculture-Forest Service, Southeastern Forest Experiment Station, Research Paper SE-1, January, 1963.

## Table 4. Yield Coefficients for Slash Pine Forests (Merchantable Wood)

| AGE | SITE INDEX 30 | | | SITE INDEX 40 | | | SITE INDEX 50 | | | SITE INDEX 60 | | | SITE INDEX 70 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Natural | | Plantation | Natural | | Plantation | Natural | | Plantation | Natural | | Plantation | Natural | | Plantation |
| (Yrs) | (Ft$^3$/A.) | (Cords/A.) | (Cords/A.) | (Ft$^3$/A.) | (Cords/A.) | (Cords/A.) | (Ft$^3$/A.) | (Cords/A.) | (Cords/A.) | (Ft$^3$/A.) | (Cords/A.) | (Cords/A.) | (Ft$^3$/A.) | (Cords/A.) | (Cords/A.) |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | .1 | .7 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 1.1 | 2.1 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | .1 | .6 | 430 | 4.7 | 4.5 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 90 | 1.0 | 2.7 | 810 | 8.8 | 7.2 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | .3 | 1.3 | 230 | 2.5 | 5.3 | 1200 | 13.0 | 10.8 |
| 11 | 0 | 0 | 0 | 0 | 0 | .4 | 100 | 1.1 | 3.0 | 500 | 5.4 | 8.3 | 1460 | 15.9 | 14.5 |
| 12 | 0 | 0 | .2 | 60 | .7 | 1.3 | 250 | 2.7 | 4.8 | 700 | 7.6 | 11.4 | 1660 | 18.0 | 18.5 |
| 13 | 80 | .9 | .8 | 150 | 1.6 | 2.2 | 410 | 4.5 | 6.6 | 870 | 9.5 | 14.6 | 1810 | 19.7 | 23.3 |
| 14 | 140 | 1.5 | 1.4 | 260 | 2.8 | 3.2 | 530 | 5.8 | 8.2 | 1020 | 11.1 | 17.3 | 1960 | 21.3 | 27.6 |
| 15 | 190 | 2.1 | 2.1 | 350 | 3.8 | 4.2 | 640 | 7.0 | 9.8 | 1160 | 12.6 | 19.7 | 2110 | 22.9 | 31.3 |
| 16 | 240 | 2.6 | 2.9 | 420 | 4.6 | 5.5 | 730 | 7.9 | 11.4 | 1270 | 13.8 | 22.1 | 2220 | 24.1 | 34.6 |
| 17 | 290 | 3.2 | 3.8 | 480 | 5.2 | 6.7 | 820 | 8.9 | 12.9 | 1380 | 15.0 | 24.3 | 2320 | 25.2 | 37.8 |
| 18 | 340 | 3.7 | 4.9 | 550 | 6.0 | 7.8 | 910 | 9.9 | 14.4 | 1480 | 16.1 | 26.5 | 2420 | 26.3 | 40.4 |
| 19 | 390 | 4.2 | 6.0 | 620 | 6.7 | 8.9 | 990 | 10.8 | 15.8 | 1580 | 17.2 | 28.5 | 2520 | 27.4 | 42.9 |
| 20 | 440 | 4.8 | 7.0 | 690 | 7.5 | 10.0 | 1070 | 11.6 | 17.2 | 1680 | 18.3 | 30.3 | 2620 | 28.5 | 45.2 |
| 21 | 490 | 5.3 | 8.0 | 750 | 8.2 | 11.1 | 1140 | 12.4 | 18.5 | 1770 | 19.2 | 32.0 | 2700 | 29.4 | 47.2 |
| 22 | 550 | 6.0 | 9.0 | 810 | 8.8 | 12.1 | 1220 | 13.3 | 19.7 | 1860 | 20.2 | 33.6 | 2780 | 30.2 | 49.0 |
| 23 | 610 | 6.6 | 9.9 | 880 | 9.6 | 13.1 | 1300 | 14.1 | 20.8 | 1940 | 21.1 | 35.1 | 2850 | 31.0 | 50.7 |
| 24 | 670 | 7.3 | 10.8 | 950 | 10.3 | 14.1 | 1380 | 15.0 | 21.9 | 2020 | 22.0 | 36.4 | 2920 | 31.7 | 52.3 |
| 25 | 720 | 7.8 | 11.7 | 1020 | 11.1 | 15.1 | 1460 | 15.9 | 22.9 | 2090 | 22.7 | 37.7 | 2990 | 32.5 | 53.8 |
| 26 | 780 | 8.5 | 12.6 | 1080 | 11.7 | 16.1 | 1530 | 16.6 | 23.9 | 2160 | 23.5 | 38.9 | 3060 | 33.3 | 55.1 |
| 27 | 830 | 9.0 | 13.5 | 1150 | 12.5 | 17.0 | 1600 | 17.4 | 24.9 | 2230 | 24.2 | 40.0 | 3120 | 33.9 | 56.3 |
| 28 | 880 | 9.6 | 14.3 | 1210 | 13.2 | 17.9 | 1670 | 18.2 | 25.9 | 2300 | 25.0 | 41.0 | 3170 | 34.5 | 57.4 |
| 29 | 930 | 10.1 | 15.1 | 1270 | 13.8 | 18.8 | 1740 | 18.9 | 26.8 | 2360 | 25.7 | 41.9 | 3220 | 35.0 | 58.4 |
| 30 | 990 | 10.8 | 15.9 | 1320 | 14.4 | 19.6 | 1800 | 19.6 | 27.6 | 2420 | 26.3 | 42.7 | 3260 | 35.4 | 59.3 |
| 31 | 1050 | 11.4 | 16.6 | 1380 | 15.0 | 20.3 | 1860 | 20.2 | 28.4 | 2480 | 27.0 | 43.4 | 3310 | 36.0 | 60.1 |
| 32 | 1110 | 12.1 | 17.3 | 1440 | 15.7 | 21.0 | 1920 | 20.9 | 29.2 | 2540 | 27.6 | 44.1 | 3350 | 36.4 | 60.8 |
| 33 | 1160 | 12.6 | 17.9 | 1500 | 16.3 | 21.7 | 1980 | 21.5 | 30.0 | 2590 | 28.2 | 44.7 | 3390 | 36.9 | 61.4 |
| 34 | 1210 | 13.2 | 18.5 | 1560 | 17.0 | 22.4 | 2030 | 22.1 | 30.7 | 2640 | 28.7 | 45.3 | 3430 | 37.3 | 62.0 |
| 35 | 1250 | 13.6 | 19.1 | 1610 | 17.5 | 23.0 | 2080 | 22.6 | 31.4 | 2690 | 29.2 | 45.8 | 3470 | 37.7 | 62.6 |
| 36 | 1290 | 14.0 | 19.7 | 1660 | 18.0 | 23.6 | 2130 | 23.2 | 32.0 | 2740 | 29.8 | 46.3 | 3510 | 38.2 | 63.1 |
| 37 | 1340 | 14.6 | 20.2 | 1710 | 18.6 | 24.2 | 2180 | 23.7 | 32.6 | 2790 | 30.3 | 46.8 | 3550 | 38.6 | 63.5 |
| 38 | 1390 | 15.1 | 20.7 | 1760 | 19.1 | 24.8 | 2230 | 24.2 | 33.1 | 2830 | 30.8 | 47.2 | 3580 | 38.9 | 63.9 |
| 39 | 1440 | 15.7 | 21.2 | 1810 | 19.7 | 25.3 | 2280 | 24.8 | 33.5 | 2870 | 31.2 | 47.5 | 3610 | 39.2 | 64.2 |
| 40 | 1490 | 16.2 | 21.6 | 1860 | 20.2 | 25.7 | 2320 | 25.2 | 33.9 | 2910 | 31.6 | 47.8 | 3640 | 39.6 | 64.5 |
| 41 | 1530 | 16.6 | 22.0 | 1910 | 20.8 | 26.1 | 2360 | 25.7 | 34.3 | 2950 | 32.1 | 48.1 | 3670 | 39.9 | 64.8 |
| 42 | 1570 | 17.1 | 22.4 | 1950 | 21.2 | 26.5 | 2400 | 26.1 | 34.7 | 2990 | 32.5 | 48.4 | 3700 | 40.2 | 65.0 |
| 43 | 1610 | 17.5 | 22.8 | 1990 | 21.6 | 26.9 | 2450 | 26.6 | 35.1 | 3030 | 32.9 | 48.6 | 3730 | 40.5 | 65.2 |
| 44 | 1660 | 18.0 | 23.2 | 2040 | 22.2 | 27.3 | 2490 | 27.1 | 35.5 | 3060 | 33.3 | 48.8 | 3750 | 40.8 | 65.4 |
| 45 | 1700 | 18.5 | 23.6 | 2080 | 22.6 | 27.6 | 2530 | 27.5 | 35.8 | 3090 | 33.6 | 49.0 | 3770 | 41.0 | 65.6 |
| 46 | 1740 | 18.9 | 23.9 | 2120 | 23.0 | 27.9 | 2570 | 27.9 | 36.1 | 3120 | 33.9 | 49.2 | 3800 | 41.3 | 65.8 |
| 47 | 1780 | 19.4 | 24.2 | 2160 | 23.5 | 28.2 | 2610 | 28.4 | 36.4 | 3150 | 34.2 | 49.4 | 3820 | 41.5 | 66.0 |
| 48 | 1820 | 19.8 | 24.5 | 2200 | 23.9 | 28.5 | 2650 | 28.8 | 36.7 | 3180 | 34.6 | 49.6 | 3840 | 41.7 | 66.2 |
| 49 | 1860 | 20.2 | 24.8 | 2240 | 24.4 | 28.8 | 2680 | 29.1 | 36.9 | 3210 | 34.9 | 49.8 | 3860 | 42.0 | 66.3 |
| 50 | 1900 | 20.7 | 25.0 | 2270 | 24.7 | 29.0 | 2710 | 29.5 | 37.1 | 3240 | 35.2 | 49.9 | 3880 | 42.2 | 66.4 |

Conversion Factor: 1 Cord = 92 Cubic Feet of Wood and Bark.

Sources: Langdon, O. Gordon, *Yield of Unmanaged Slash Pine Stands in South Florida*, U. S. Department of Agriculture—Forest Service, Southeastern Forest Experiment Station, Station Paper No. 123, June, 1961.

Bennett, Frank A., *Growth and Yield of Slash Pine Plantations*, U. S. Department of Agriculture—Forest Service, Southeastern Forest Experiment Station, Research Paper SE-1, January, 1963.

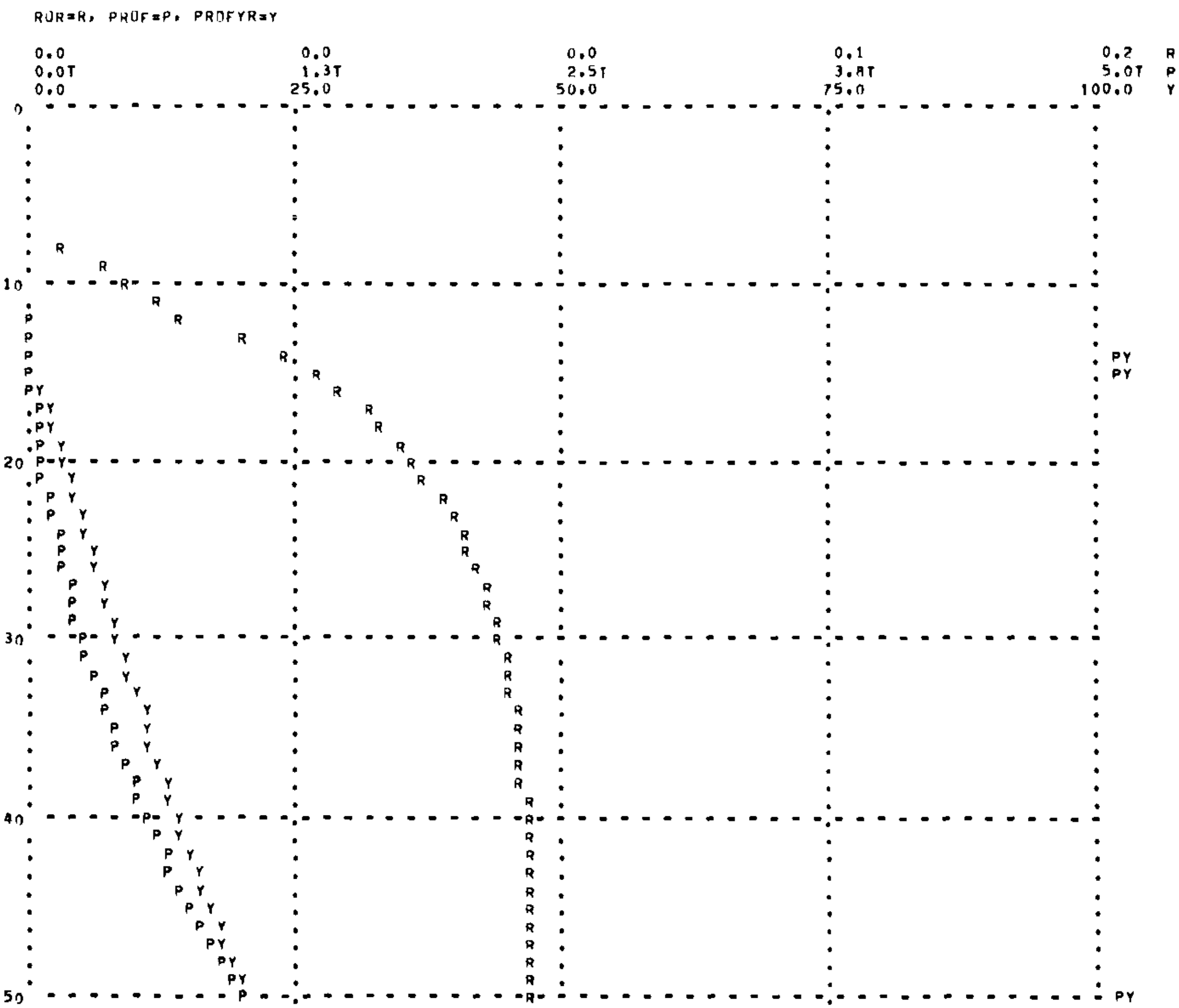


Figure 4. Results of the Forest Investment Model for SI 30 Natural Growth Land

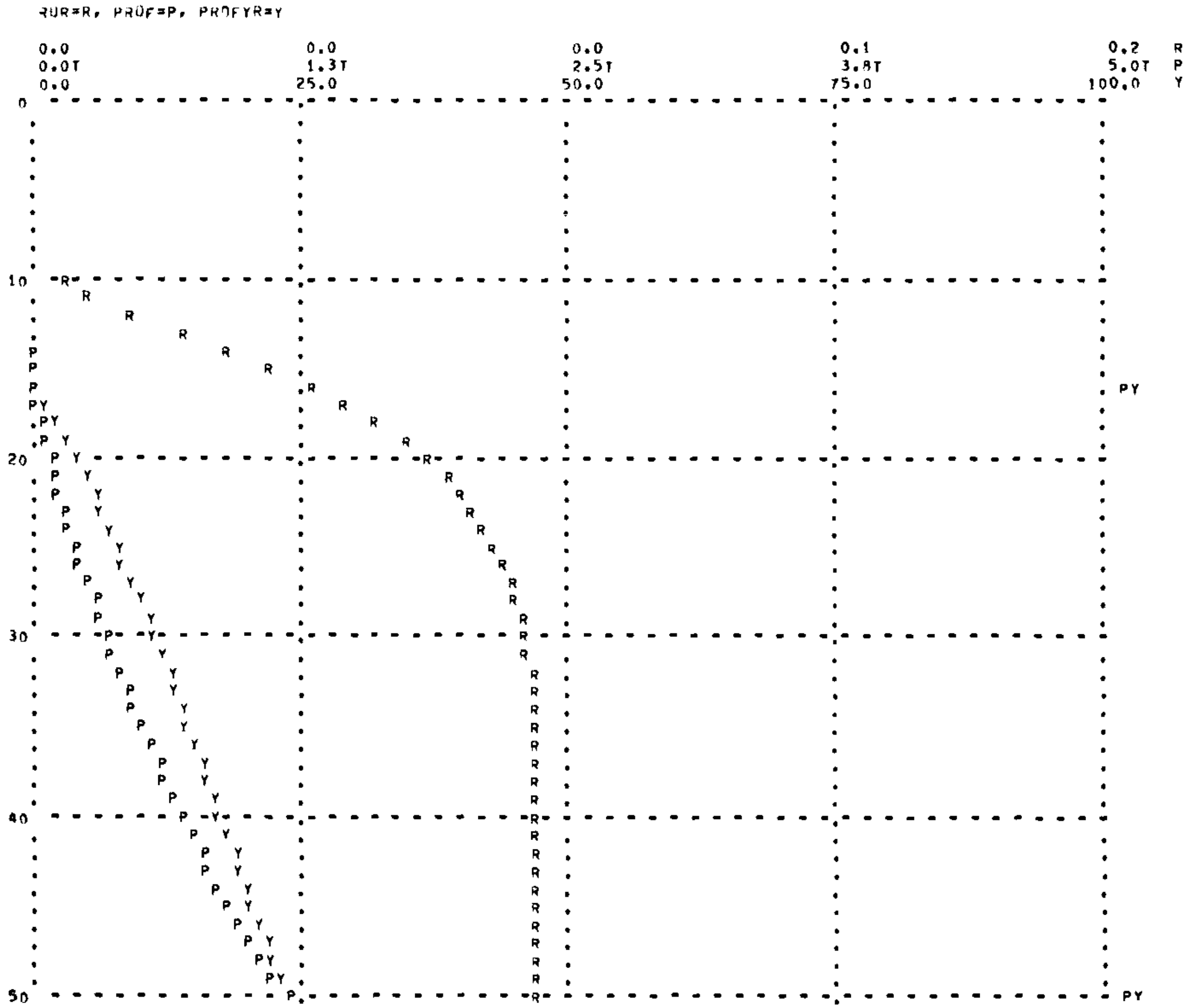


Figure 5. Results of the Forest Investment Model for SI 30 Plantation Land

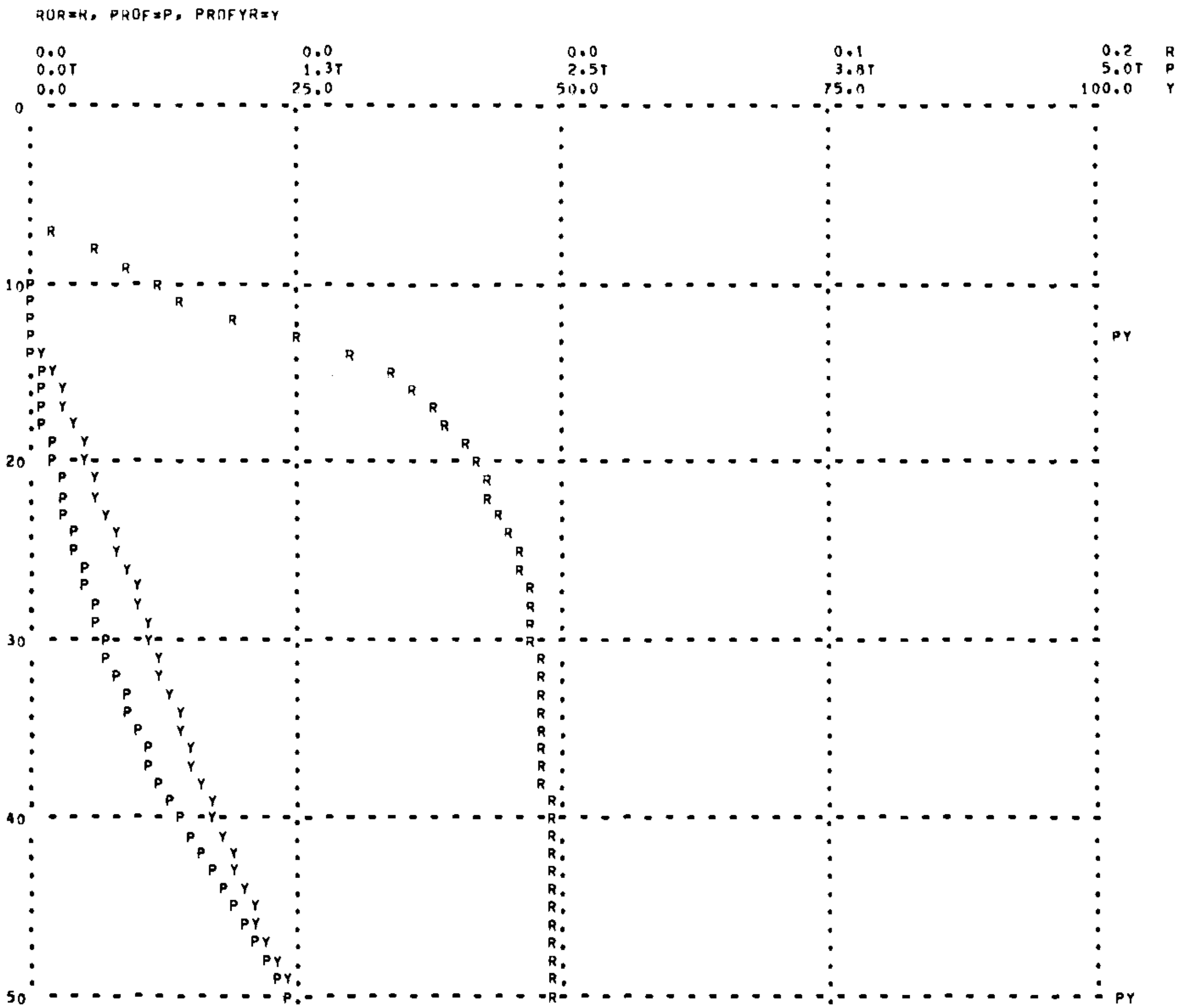


Figure 6. Results of the Forest Investment Model for SI 40 Natural Growth Land

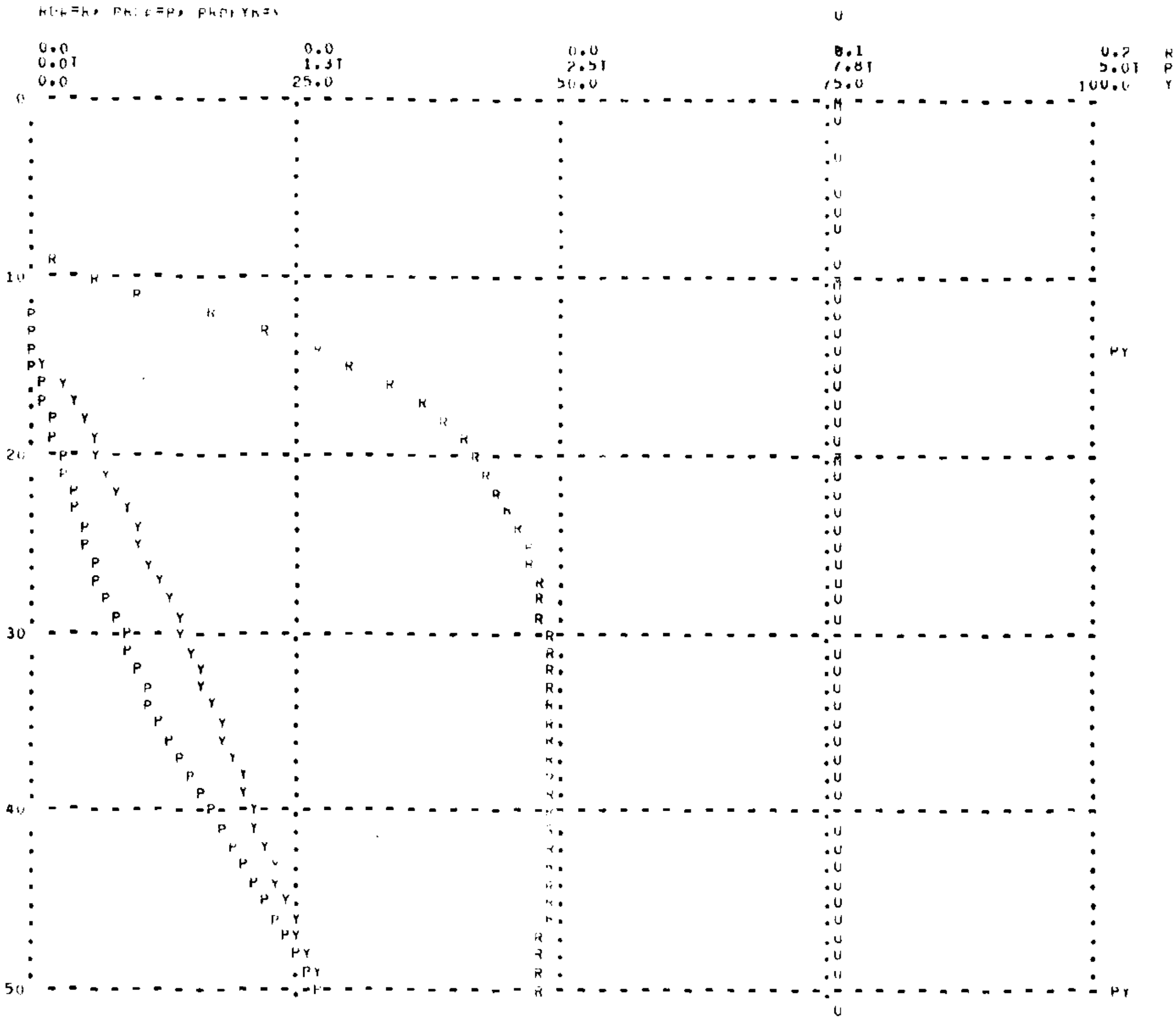

Figure 7. Results of the Forest Investment Model for SI 40 Plantation Land

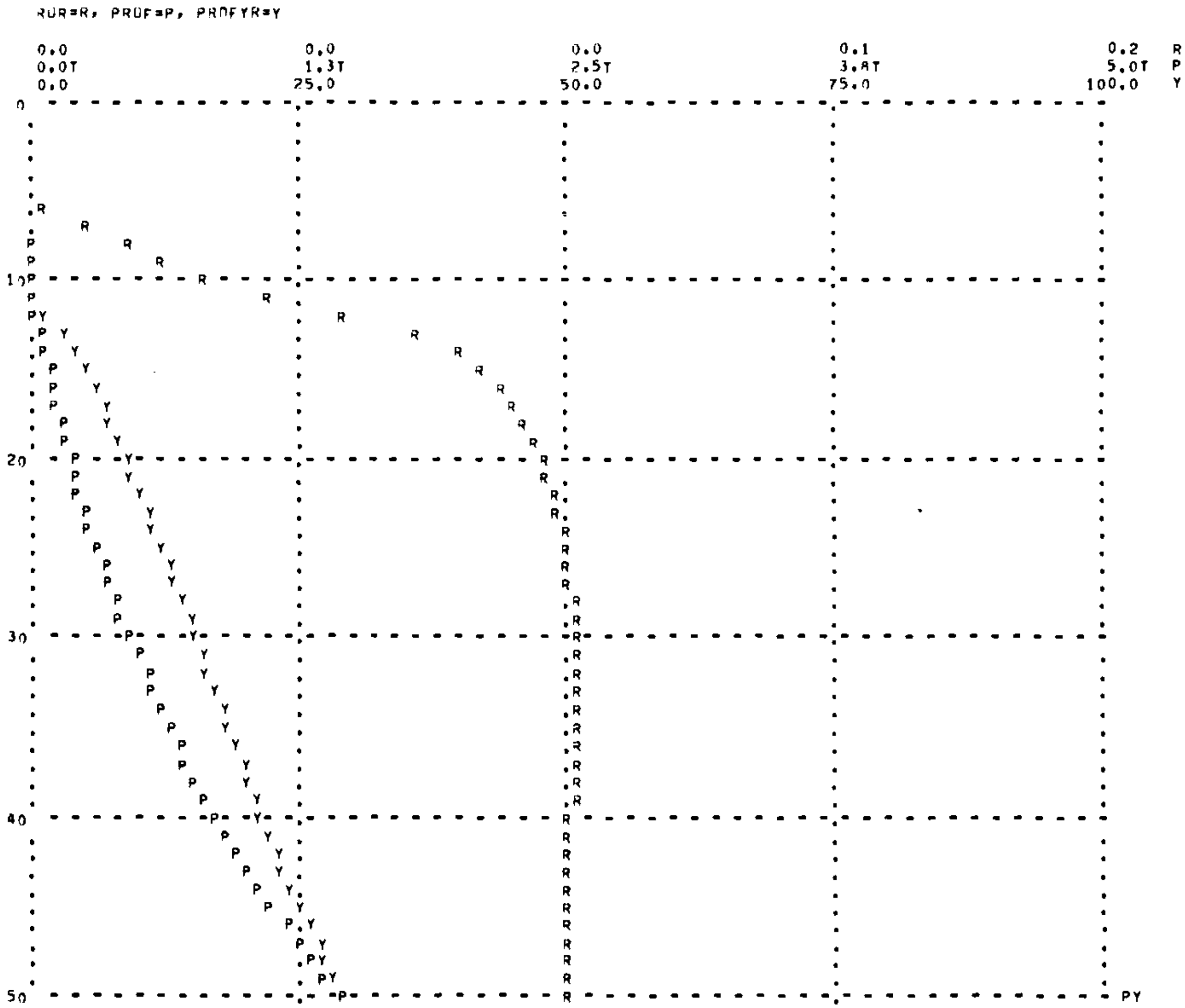


Figure 8. Results of the Forest Investment Model for SI 50 Natural Growth Land

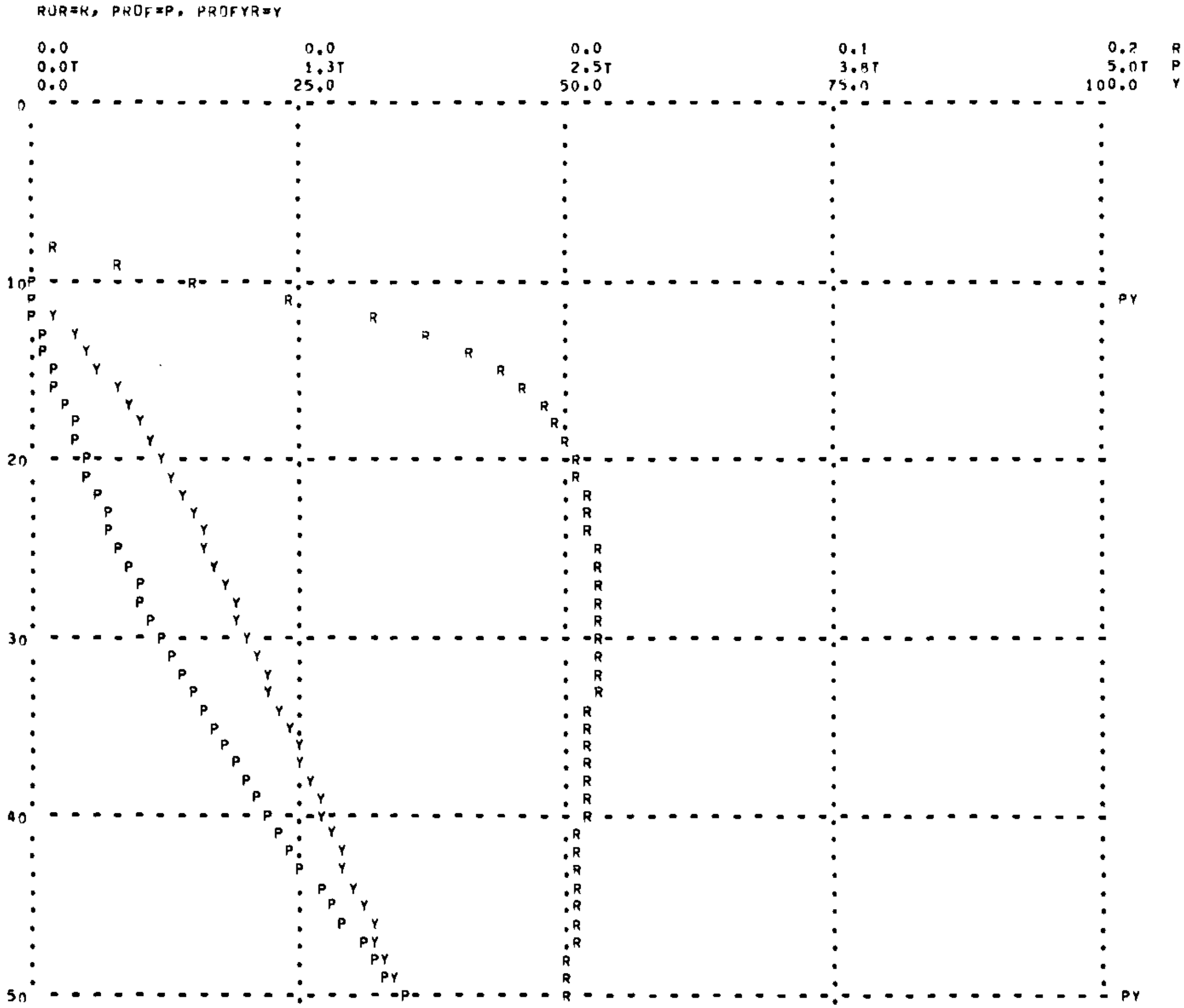


Figure 9. Results of the Forest Investment Model for SI 50 Plantation Land

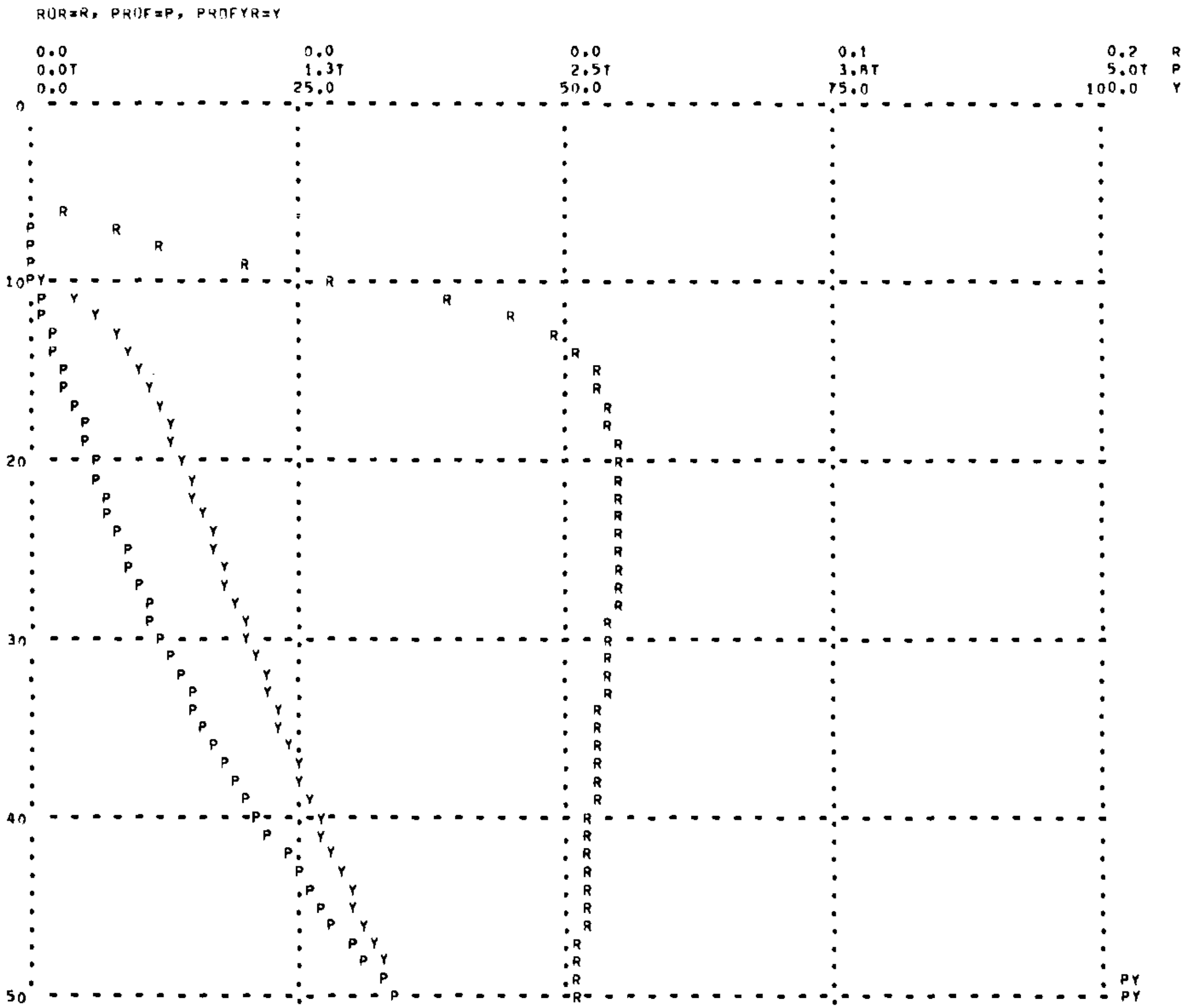


Figure 10. Results of the Forest Investment Model for SI 60 Natural Growth Land

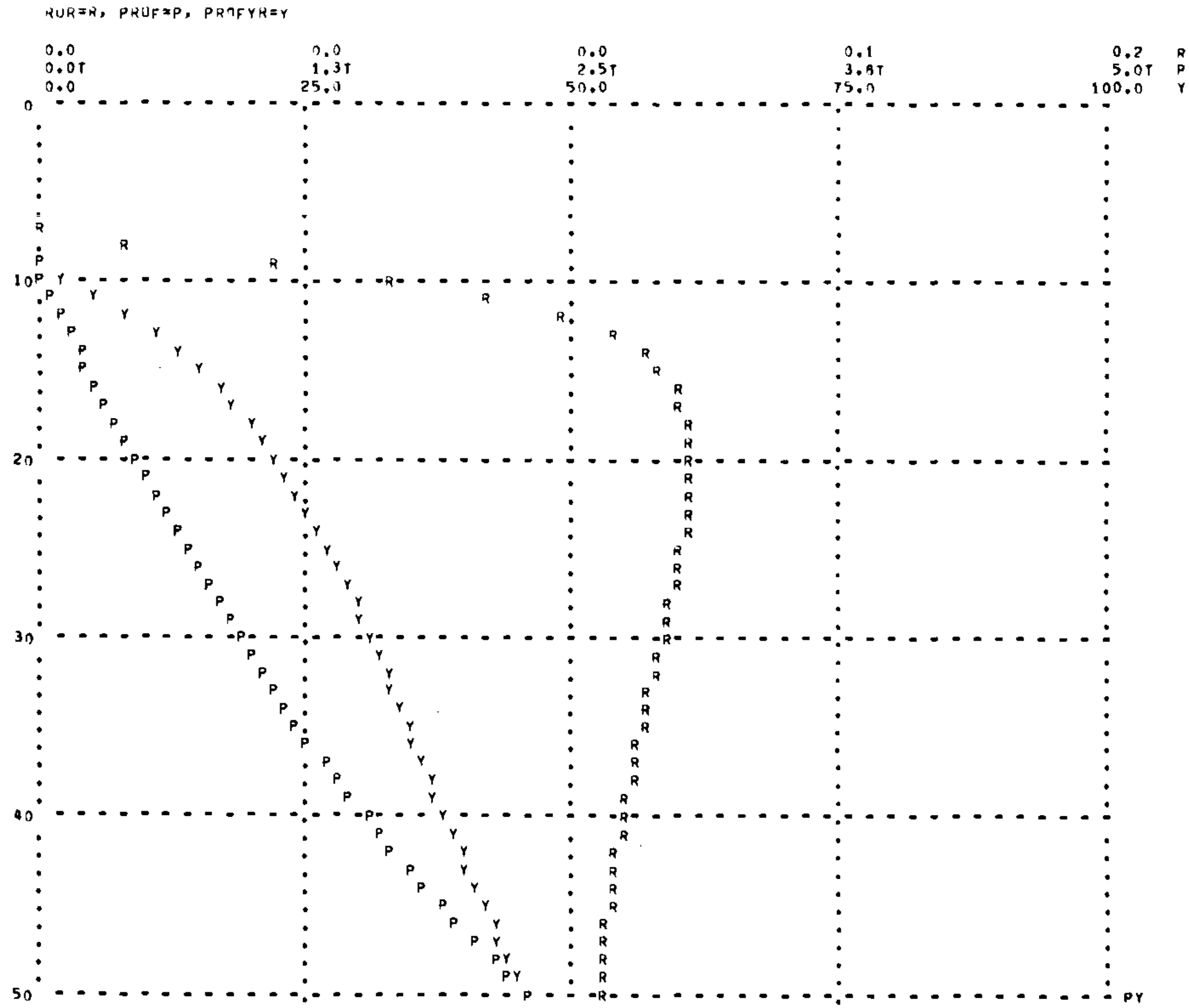


Figure 11. Results of the Forest Investment Model for SI 60 Plantation Land

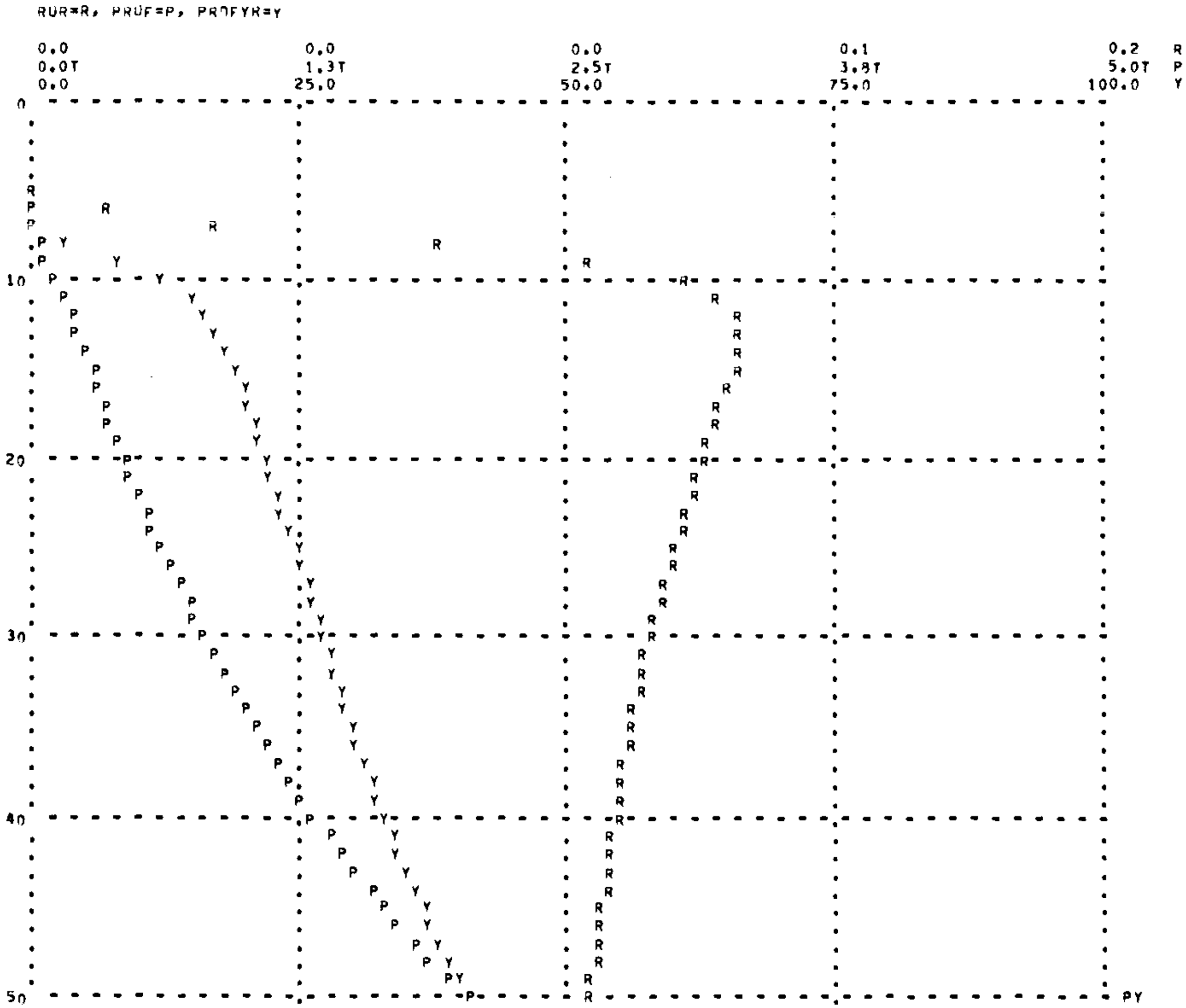


Figure 12. Results of the Forest Investment Model for SI 70 Natural Growth Land

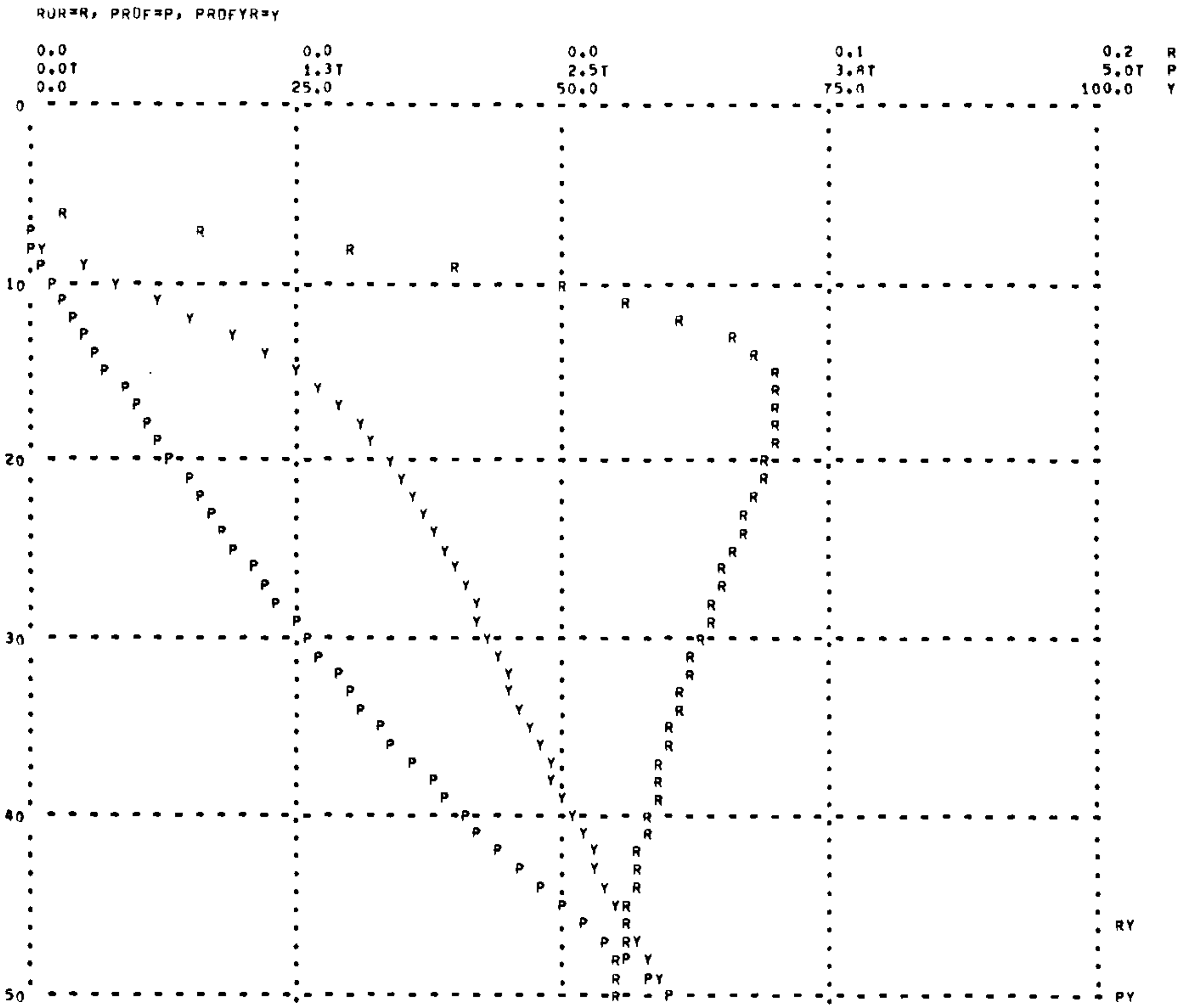


Figure 13. Results of the Forest Investment Model for SI 70 Plantation Land

Interpretation of the graphs is as follows: Consider Figure 4 for Site Index 30 Natural Growth Land. Each point on the rate of return curve represents the rate of return on investment if an acre of land of site index 30 in natural growth status were cut in a particular year (age of stand). Thus it can be seen that the stand must be 15 years old or greater in order to realize a rate of return greater than zero. Also, the rate of return increases to a value of .04470 per cent at a stand age of 50 (exact values of variables are obtained from a tabular output). Profit and profit per year also increase with increasing stand age.

Comparison of the rate of return curves for the ten runs yields some significant results. It is noted that the curves for natural and plantation land of the same site index are approximately parallel over the range of stand ages considered. For all site indices, the numerical values on the curve representing plantation land are slightly larger than the corresponding values for natural growth land. It is also noted that the numerical values of rate of return increase with increasing site index.

The shape of the rate of return curves differs significantly by site index. In site index 30 the rate of return increases with increasing stand age over the range of stand ages considered. As the site index increases, however, the rate of return curve shows a definite peaking characteristic prior to a stand age of 50. The age at which the maximum rate of return occurs decreases with increasing site index. In site index 70, peaking occurs prior to stand age 18 for both natural growth and plantation land. A summary of the ten runs showing the maximum values of rate of return and the stand age at which they occur is shown in Table 5. It should be clear that from profitability considerations, the maximum point on the rate of return curve represents the optimal rotation age for the site index and management policy under consideration.

A sample tabular output of the forest investment model for site index 30 natural growth land is shown in Appendix B.

Table 5. Optimal Rotation Ages

| Run | Site Index | Policy | Maximum Rate of Return | Optimal Rotation Age |
|---|---|---|---|---|
| 1 | 30 | Natural | .04470 | 50 |
| 2 | 30 | Plantation | .04480 | 42-45* |
| 3 | 40 | Natural | .04732 | 44 |
| 4 | 40 | Plantation | .04809 | 38 |
| 5 | 50 | Natural | .05162 | 32 |
| 6 | 50 | Plantation | .05557 | 28 |
| 7 | 60 | Natural | .06023 | 22 |
| 8 | 60 | Plantation | .07259 | 20 |
| 9 | 70 | Natural | .08159 | 13 |
| 10 | 70 | Plantation | .09073 | 17 |

*Same rate of return for four consecutive years.

# CHAPTER IV

# THE FOREST MANAGEMENT MODEL

The forest management model is formulated as a deterministic difference equation model. It was originally intended to construct the model in the DYNAMO computer language in order to represent the dynamic, time-dependent relationships that exist in describing the long-term behavior of the forest. However, the scope of the model far exceeded the capability of the Burroughs B5500 DYNAMO translator. The dynamic nature of the model was retained, however, by formulating the model in the general purpose ALGOL computer language. In fact, it was soon discovered that the increased flexibility gained by using a general purpose language was of extreme importance in successfully formulating the many different constructs present in the model.

## General Description

The forest management model is designed to represent a heterogeneous forest resource as might be controlled by a typical pulp-producing company. The model is intended to simulate the long-term behavior of such a limited resource under conditions of a continuing demand for pulp.

The forest is conceived as a dynamic, input-output system. It receives inputs in the form of forest management treatments, grows according to relatively stable silvicultural parameters, and produces an output in the form of cords of wood harvested. The forest is a renewable resource in that after harvesting it may be used to produce further yield at some time in the future.

Critical to the long-term behavior of the forest resource are the management policies representing harvesting decisions and reforestation treatments. The model possesses the dual objective of meeting a continuing demand for pulp while still achieving the maximum overall return on invested capital.

In representing a large-scale heterogeneous forest resource, some degree of simplification and abstraction is required. The model considers only a constant fixed amount of land. All land is subdivided into blocks according to site index, forest management treatment, and age of stand. In order to remain compatible with the forest investment model, the same five site indices, namely 30, 40, 50, 60 and 70 are used. Further, the same two forest management treatments, natural growth and plantation, are considered. Stand ages from zero to 41 years are allowed in the model. It should be noted that stand age 41 represents all acres 41 years old or greater. This simplification is considered valid since yield for stand ages greater than 40 is relatively constant.

The model is driven by an annual demand for pulp. Annual harvesting is continued until this demand is satisfied or until the supply of merchantable wood is exhausted. In order to maximize the rate-of-return on investment, the harvesting operation is sequenced based on the rate-of-return for different blocks of land. The cutting sequence is a predetermined input to the model and is generated by a regret function based on incremental changes in rate-of-return. The sequence is designed to minimize the rate-of-return loss in harvesting many blocks of land over an extended period of time.

Forest management policies are formulated as an attempt by the forest manager to insure a continuing supply of pulp with the minimal outlay of capital for forest management. In this respect, the level of forest resources available (cords on the stump) is compared with a projected demand for pulp. The amount of investment in forest management is then based on the difference between projected demand and projected supply. The general concept of the model is shown in Figure 14.

In method of formulation, the model retains much of the nature and concept of the DYNAMO computer language. It is felt that this concept, which relates the flow of acres of land through different levels--or blocks--to the information flows which guide decisions made in the model, adequately describes the system and provides an intuitive insight into the dynamic behavior of the forest.

Timekeeping in the model is performed in a manner that closely approximates DYNAMO. Definition of timekeeping subscripts is as follows:

| Subscript | Definition |
|---|---|
| J | Value at the previous point in time |
| K | Value at the present point in time |
| L | Value at the next point in time |
| JK | Value during the interval from J to K |
| KL | Value during the interval from K to L |

The time interval used in the model is one year. The model is run for a period of 100 years. It should be noted that values during an interval of time are referenced to the beginning of the interval. For example, the KL subscript for a value for the interval from time 5 to time 6 is subscripted 5.

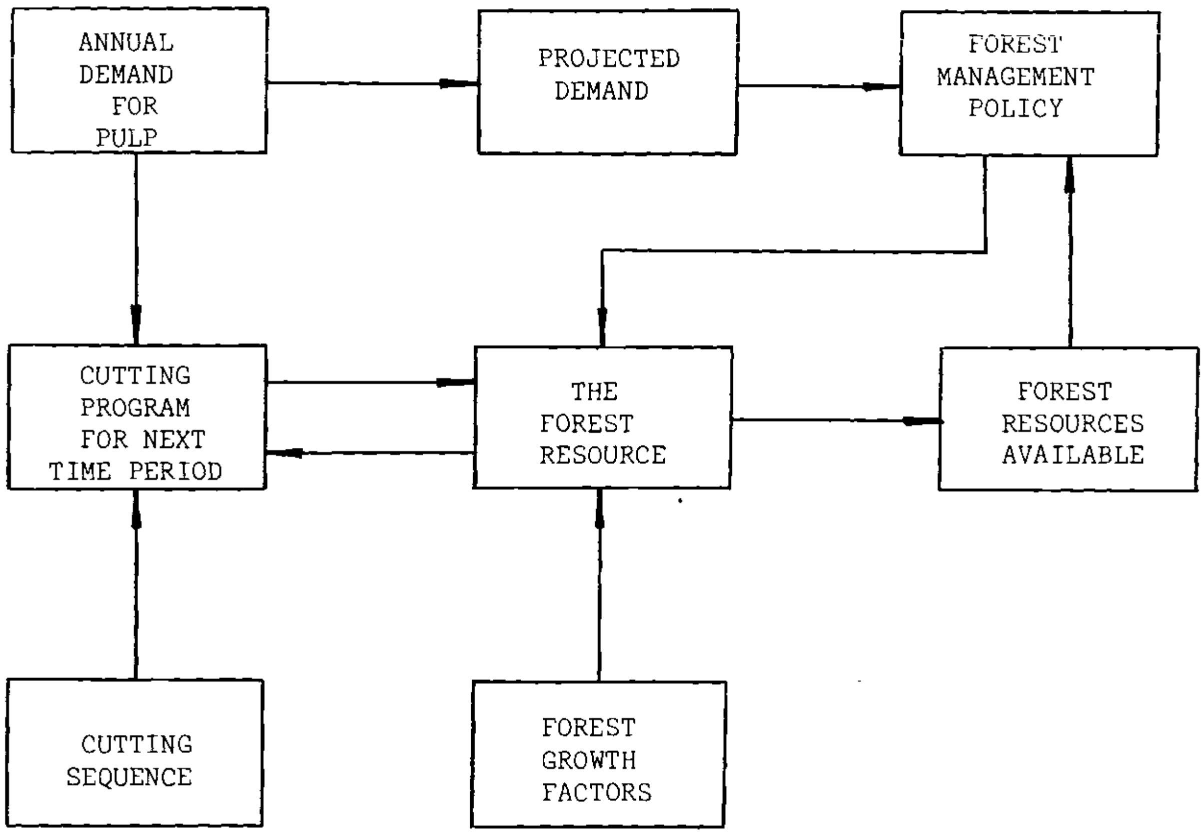


Figure 14. Concept of the Forest Management Model

The model is concerned with both acres and cords of wood. All acres of land considered in the model are categorized into blocks. Acres "flow" from block to block according to cutting rates, planting rates and growth rates. Acres are converted to cord equivalents through the same set of yield coefficients used in the forest investment model. Cord equivalents are used in establishing cutting rates required to support the demand for pulp. An abbreviated flow diagram showing the flow of acres through the system is shown in Figure 15. Symbols used in this figure are as follows:

ACLXP[K] - Acres of Cleared Land of Site Index XO to be Planted in Plantation Status at Some Time in the Future (Acres)
PRXO[KL] - Planting Rate for Site Index XO Plantation Land (Acres/Year)
AXP[K,Z] - Acres of Site Index XO Plantation Land Z Years Old (Acres)
AXN[K,Z] - Acres of Site Index XO Natural Growth Land Z Years Old (Acres)
GXP[KL,Z] - Growth Rate for Site Index XO Plantation Land Z Years Old (Acres/Year)
GXN[KL,Z] - Growth Rate for Site Index XO Natural Growth Land Z Years Old (Acres/Year)
CXP[KL,Z] - Clear Cutting Rate for Site Index XO Plantation Land Z Years Old (Acres/Year)
SXP[KL,Z] - Selective Cutting Rate for Site Index XO Plantation Land Z Year Old (Acres/Year)
CXN[KL,Z] - Clear Cutting Rate for Site Index XO Natural Growth Land Z Years Old (Acres/Year)
SXN[KL,Z] - Selective Cutting Rate for Site Index XO Natural Growth Land Z Years Old (Acres/Year)

Since the time interval in the simulation is one year it is evident that each year every block of land is evaluated and each acre is either clear cut, selective cut, or allowed to grow for another year. Forest management policy provides the selection between clear cutting and selective cutting.

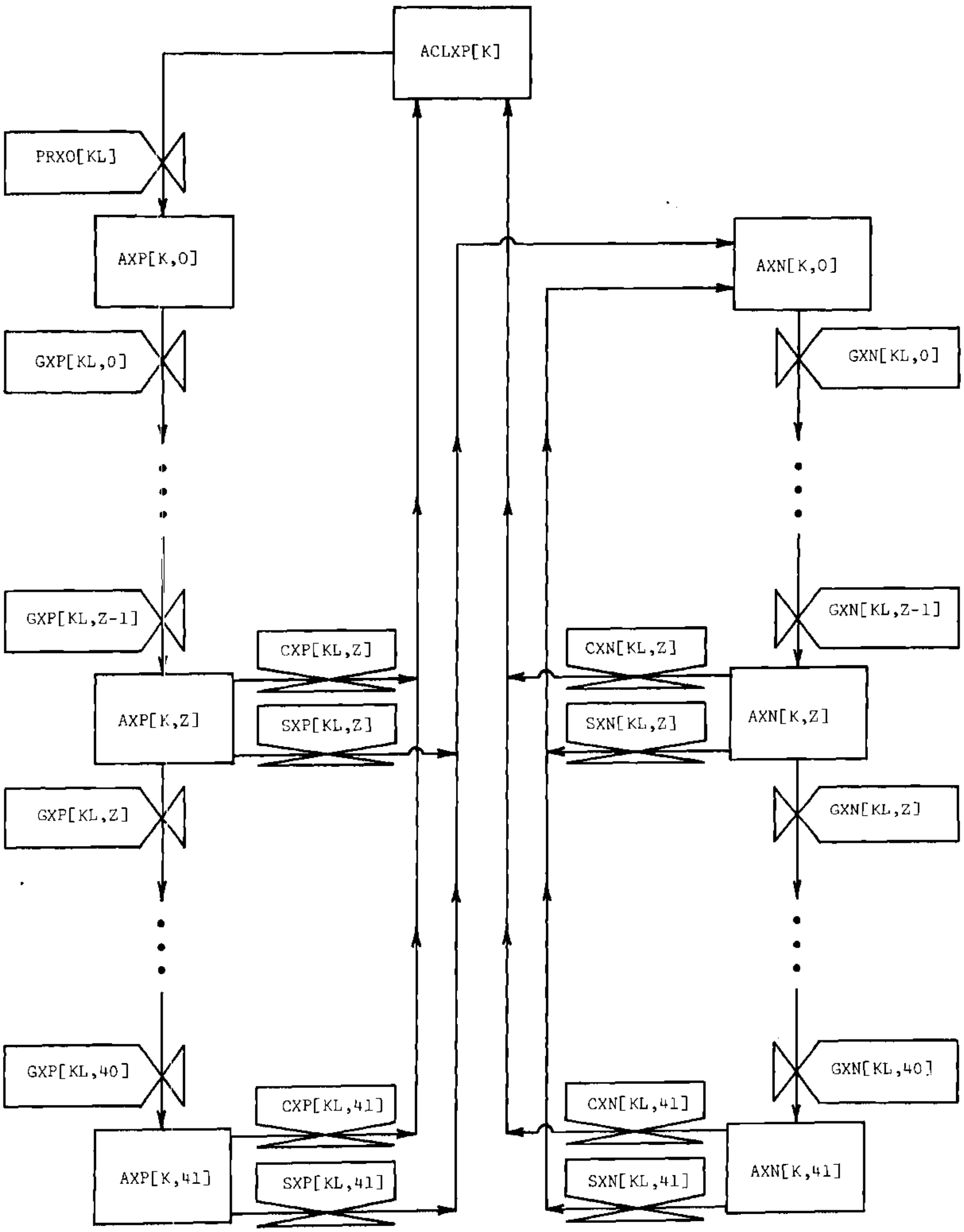


Figure 15. Abbreviated Flow Diagram of the Forest Management Model

It should be noted that Figure 15 shows the abbreviated flow diagram for only one site index. The model consists of five similar segments each representing one site index. System dynamics between the five site indices is provided through the cutting sequence. Since the sequence is based on rate-of-return considerations, harvesting of consecutive blocks in the sequence may skip from one site index to another and from plantation to natural growth land. The level of demand and the availability of resources in the various blocks determines how many and which blocks are to be harvested in any given year.

Output of the forest management model is a set of values for each of the 100 time periods in the simulation. Analysis of trends of significant variables over the 100-year time period is used in evaluating the alternative policy being tested.

## Development of Cutting Sequence

The cutting sequence used in the forest management model is a direct development of the results obtained from the forest investment model. The sequence was developed as follows:

Rate-of-return values for the ten forest management treatments (five site indices and two management policies) were tabulated for harvesting at stand ages of zero through 41 years. (Note that stand age 41 represents stands 41 years old or greater.) Incremental changes in rate-of-return were then determined by comparing the rate-of-return for harvesting a given treatment at stand age n with the rate-of-return for harvesting the same treatment at stand age n + 1. The incremental changes in rate-of-return for the 410 blocks of land in the model were then sequenced in such a way as to minimize the rate-of-return loss associated with allowing a block of land to grow for an additional year. The resulting cutting sequence consists of three phases as follows:

Phase I

Phase I includes blocks for which the value of rate-of-return (ROR) is positive and the incremental change in rate-of-return (ICROR) is negative. Such blocks represent segments of the rate-of-return curves in Figures 4 through 13 which have a negative slope. In a silvicultural context, they represent blocks which have already passed the years of maximum incremental annual growth. The 124 blocks in phase I are sequenced in the order of decreasing ICROR loss. Thus the block with the maximum negative ICROR is scheduled to be cut first and the block with the minimum negative ICROR is scheduled to be cut last. This represents a management policy of always cutting first the block which will show the maximum ROR loss if let grow another year.

Phase II

Phase II includes blocks for which the value of ROR is positive and the value of ICROR is positive. These blocks represent segments of the rate-of-return curves in Figures 4 through 13 which have a positive slope and a positive ROR. Silviculturally, these blocks have not yet passed the years of maximum incremental annual growth. The 177 blocks in phase II are sequenced in the order of increasing ICROR gain. Thus the block with the minimum positive ICROR is scheduled to be cut first and the block with the maximum positive ICROR is scheduled to be cut last. This represents a management policy of cutting last the block which will show the maximum ROR gain if let grow another year.

### Phase III

Phase III includes all blocks for which the value of ROR is negative. These blocks represent young stands which have not yet developed sufficient potential yield to make harvesting profitable. Since harvesting of any of the 109 blocks in phase III represents a loss, none of these blocks is included in the cutting sequence.

The complete cutting sequence in the forest management model consists of 301 blocks of land. This sequence, including block description and incremental change in rate of return is shown in Table 6. In all cases where ties arose in ICROR, the block with the maximum yield is scheduled for cutting first. The data used in developing the cutting sequence is shown in Appendix C.

## Model Formulation

Formulation of the forest management model is to be discussed in terms of the ALGOL computer program developed for model implementation. Discussion will follow the computer flow diagram shown in Figure 16. This diagram shows only the main program segments and the associated computation sequence. Expansion of the program logic will be provided for each program segment. Since the model consists of over 1000 equations, each equation will not be discussed in detail. A complete listing of the forest management model is shown in Appendix D.

### Bookkeeping and Declarations

The initial program segment consists of the systems equations and declarations necessary to implement the model on the Burroughs B5500 computer and a listing of definitions of variables used in the model.

Table 6. Cutting Sequence

| Sequence | Block Description SI | P or N | Age | Incremental Change in ROR ROR Loss | Yield (Shown Only for Ties in ICROR) |
|---|---|---|---|---|---|
| 1 | 70 | P | 21 | .00130 | |
| 2 | 70 | P | 25 | .00129 | 53.8 |
| 3 | 70 | P | 22 | .00129 | 49.0 |
| 4 | 70 | P | 23 | .00128 | |
| 5 | 70 | P | 26 | .00127 | |
| 6 | 70 | P | 24 | .00125 | 52.3 |
| 7 | 70 | N | 16 | .00125 | 24.1 |
| 8 | 70 | P | 27 | .00124 | |
| 9 | 70 | P | 28 | .00120 | 57.4 |
| 10 | 70 | P | 20 | .00120 | 45.2 |
| 11 | 70 | N | 21 | .00120 | 29.4 |
| 12 | 70 | P | 29 | .00117 | 58.9 |
| 13 | 70 | N | 20 | .00117 | 28.5 |
| 14 | 70 | P | 30 | .00115 | 59.3 |
| 15 | 70 | N | 15 | .00115 | 22.9 |
| 16 | 70 | N | 17 | .00114 | |
| 17 | 70 | N | 23 | .00112 | |
| 18 | 70 | P | 31 | .00111 | |
| 19 | 70 | P | 32 | .00109 | 60.8 |
| 20 | 70 | N | 22 | .00109 | 30.2 |
| 21 | 70 | N | 18 | .00106 | |
| 22 | 70 | P | 33 | .00103 | |
| 23 | 70 | N | 26 | .00098 | 33.3 |
| 24 | 70 | N | 19 | .00098 | 27.4 |
| 25 | 70 | P | 34 | .00095 | 62.0 |
| 26 | 70 | P | 19 | .00095 | 42.9 |
| 27 | 70 | P | 35 | .00094 | 62.6 |
| 28 | 70 | N | 29 | .00094 | 35.0 |
| 29 | 70 | P | 36 | .00093 | 63.1 |
| 30 | 70 | N | 24 | .00093 | 31.7 |
| 31 | 70 | N | 28 | .00092 | |
| 32 | 70 | N | 27 | .00091 | |
| 33 | 70 | P | 37 | .00087 | |
| 34 | 70 | P | 38 | .00086 | |
| 35 | 70 | N | 25 | .00085 | |
| 36 | 70 | P | 39 | .00082 | 64.2 |
| 37 | 70 | N | 31 | .00082 | 36.0 |
| 38 | 60 | P | 30 | .00079 | |
| 39 | 70 | P | 40 | .00077 | 64.5 |
| 40 | 60 | P | 29 | .00077 | 41.9 |
| 41 | 70 | P | 41 | .00076 | |
| 42 | 60 | P | 28 | .00075 | |

Table 6. Cutting Sequence (Continued)

| Sequence | Block Description SI | P or N | Age | Incremental Change in ROR ROR Loss | Yield (Shown Only for Ties in ICROR) |
|---|---|---|---|---|---|
| 43 | 60 | P | 32 | .00074 | 44.1 |
| 44 | 60 | P | 31 | .00074 | 43.4 |
| 45 | 70 | P | 18 | .00072 | 40.4 |
| 46 | 60 | P | 27 | .00072 | 40.0 |
| 47 | 70 | N | 33 | .00072 | 36.9 |
| 48 | 70 | N | 30 | .00072 | 35.4 |
| 49 | 60 | P | 34 | .00071 | 45.3 |
| 50 | 60 | P | 33 | .00071 | 44.7 |
| 51 | 60 | P | 26 | .00069 | 38.9 |
| 52 | 70 | N | 32 | .00069 | 36.4 |
| 53 | 70 | N | 34 | .00068 | |
| 54 | 60 | P | 35 | .00067 | |
| 55 | 60 | P | 38 | .00066 | |
| 56 | 60 | P | 37 | .00064 | 46.8 |
| 57 | 60 | P | 36 | .00064 | 46.3 |
| 58 | 60 | P | 25 | .00064 | 37.7 |
| 59 | 60 | P | 39 | .00062 | 47.5 |
| 60 | 70 | N | 37 | .00062 | 38.6 |
| 61 | 70 | N | 36 | .00060 | 38.2 |
| 62 | 60 | P | 23 | .00060 | 35.1 |
| 63 | 60 | P | 40 | .00059 | 47.8 |
| 64 | 70 | N | 38 | .00059 | 38.9 |
| 65 | 60 | P | 24 | .00059 | 36.4 |
| 66 | 70 | N | 35 | .00057 | |
| 67 | 60 | P | 41 | .00055 | |
| 68 | 70 | N | 40 | .00053 | 39.6 |
| 69 | 70 | P | 17 | .00053 | 37.8 |
| 70 | 70 | N | 39 | .00050 | |
| 71 | 70 | N | 41 | .00049 | |
| 72 | 60 | P | 22 | .00041 | |
| 73 | 60 | N | 33 | .00040 | |
| 74 | 60 | N | 29 | .00039 | |
| 75 | 60 | N | 34 | .00038 | |
| 76 | 60 | N | 38 | .00037 | |
| 77 | 60 | N | 24 | .00036 | |
| 78 | 50 | P | 38 | .00035 | 33.1 |
| 79 | 60 | N | 39 | .00035 | 31.2 |
| 80 | 60 | N | 31 | .00035 | 27.0 |
| 81 | 60 | N | 36 | .00034 | |
| 82 | 50 | P | 39 | .00033 | 33.5 |
| 83 | 60 | N | 32 | .00033 | 27.6 |
| 84 | 60 | N | 26 | .00033 | 23.5 |

Table 6. Cutting Sequence (Continued)

| Sequence | Block Description SI | P or N | Age | Incremental Change in ROR ROR Loss | Yield (Shown Only for Ties in ICROR) |
|---|---|---|---|---|---|
| 85 | 60 | N | 41 | .00032 | 32.1 |
| 86 | 60 | N | 37 | .00032 | 30.3 |
| 87 | 50 | P | 40 | .00031 | 33.9 |
| 88 | 60 | N | 28 | .00031 | 25.0 |
| 89 | 50 | P | 41 | .00030 | 34.3 |
| 90 | 50 | P | 37 | .00030 | 32.6 |
| 91 | 60 | P | 21 | .00028 | |
| 92 | 60 | N | 40 | .00027 | 31.6 |
| 93 | 60 | N | 35 | .00027 | 29.2 |
| 94 | 60 | N | 30 | .00027 | 26.3 |
| 95 | 50 | P | 35 | .00026 | 31.4 |
| 96 | 70 | N | 14 | .00026 | 21.3 |
| 97 | 50 | P | 36 | .00024 | |
| 98 | 60 | N | 25 | .00021 | |
| 99 | 50 | N | 39 | .00020 | 24.8 |
| 100 | 60 | N | 27 | .00020 | 24.2 |
| 101 | 50 | P | 33 | .00020 | 30.0 |
| 102 | 50 | P | 34 | .00019 | |
| 103 | 50 | N | 41 | .00018 | |
| 104 | 50 | P | 32 | .00013 | 29.2 |
| 105 | 40 | P | 39 | .00013 | 25.3 |
| 106 | 50 | N | 36 | .00013 | 18.0 |
| 107 | 50 | N | 34 | .00013 | 17.0 |
| 108 | 50 | P | 31 | .00012 | 28.4 |
| 109 | 50 | P | 30 | .00012 | 27.6 |
| 110 | 50 | P | 29 | .00012 | 26.8 |
| 111 | 40 | P | 40 | .00012 | 25.7 |
| 112 | 50 | N | 37 | .00012 | 23.7 |
| 113 | 70 | N | 13 | .00012 | 19.7 |
| 114 | 60 | P | 20 | .00011 | 30.3 |
| 115 | 40 | P | 41 | .00011 | 26.1 |
| 116 | 50 | N | 40 | .00011 | 25.2 |
| 117 | 60 | N | 23 | .00007 | |
| 118 | 40 | P | 38 | .00005 | 25.0 |
| 119 | 60 | N | 22 | .00005 | 20.2 |
| 120 | 40 | N | 41 | .00004 | |
| 121 | 50 | N | 38 | .00003 | 24.2 |
| 122 | 50 | N | 35 | .00003 | 22.6 |
| 123 | 50 | N | 33 | .00003 | 21.5 |
| 124 | 50 | N | 32 | .00002 | |

Table 6. Cutting Sequence (Continued)

| Sequence | Block Description SI | P or N | Age | Incremental Change in ROR ROR Gain | Yield (Shown Only for Ties in ICROR) |
|---|---|---|---|---|---|
| 125 | 30 | P | 40 | .00000 | 21.6 |
| 126 | 50 | N | 30 | .00000 | 19.6 |
| 127 | 50 | P | 28 | .00001 | 25.9 |
| 128 | 30 | P | 41 | .00001 | 23.9 |
| 129 | 30 | P | 39 | .00001 | 21.2 |
| 130 | 60 | N | 20 | .00003 | |
| 131 | 40 | P | 37 | .00004 | |
| 132 | 40 | P | 36 | .00005 | 23.6 |
| 133 | 40 | P | 35 | .00005 | 23.0 |
| 134 | 40 | P | 34 | .00006 | 22.4 |
| 135 | 40 | N | 39 | .00006 | 19.7 |
| 136 | 40 | N | 37 | .00009 | |
| 137 | 30 | P | 38 | .00010 | 20.7 |
| 138 | 50 | N | 31 | .00010 | 20.2 |
| 139 | 60 | P | 19 | .00011 | |
| 140 | 30 | P | 37 | .00012 | 20.2 |
| 141 | 40 | N | 35 | .00012 | 17.5 |
| 142 | 50 | P | 27 | .00013 | 24.9 |
| 143 | 30 | P | 36 | .00013 | 19.7 |
| 144 | 40 | N | 34 | .00013 | 17.0 |
| 145 | 30 | N | 40 | .00013 | 16.2 |
| 146 | 50 | N | 29 | .00014 | |
| 147 | 40 | N | 40 | .00015 | 20.2 |
| 148 | 60 | N | 21 | .00015 | 19.2 |
| 149 | 50 | P | 26 | .00016 | 23.9 |
| 150 | 50 | N | 28 | .00016 | 18.2 |
| 151 | 40 | N | 38 | .00018 | |
| 152 | 40 | P | 33 | .00019 | |
| 153 | 50 | P | 25 | .00020 | 22.9 |
| 154 | 40 | P | 32 | .00020 | 21.0 |
| 155 | 40 | N | 36 | .00021 | |
| 156 | 30 | N | 41 | .00023 | 18.5 |
| 157 | 40 | P | 31 | .00023 | 15.0 |
| 158 | 30 | N | 35 | .00023 | 13.6 |
| 159 | 50 | P | 24 | .00025 | 21.9 |
| 160 | 30 | P | 35 | .00025 | 19.1 |
| 161 | 40 | P | 30 | .00026 | 19.6 |
| 162 | 30 | N | 39 | .00026 | 15.7 |
| 163 | 30 | N | 34 | .00026 | 13.2 |
| 164 | 30 | P | 34 | .00028 | |
| 165 | 50 | N | 25 | .00029 | |
| 166 | 30 | P | 33 | .00031 | |

Table 6. Cutting Sequence (Continued)

| Sequence | Block Description SI | P or N | Age | Incremental Change in ROR ROR Gain | Yield (Shown Only for Ties in ICROR) |
|---|---|---|---|---|---|
| 167 | 40 | N | 32 | .00032 | 15.7 |
| 168 | 30 | N | 37 | .00032 | 14.6 |
| 169 | 30 | P | 32 | .00034 | |
| 170 | 50 | N | 27 | .00035 | |
| 171 | 50 | N | 26 | .00040 | 16.6 |
| 172 | 30 | N | 38 | .00040 | 15.1 |
| 173 | 40 | N | 30 | .00040 | 14.4 |
| 174 | 40 | N | 33 | .00041 | |
| 175 | 70 | N | 12 | .00042 | |
| 176 | 40 | P | 29 | .00043 | |
| 177 | 40 | N | 29 | .00045 | |
| 178 | 50 | P | 23 | .00046 | |
| 179 | 70 | P | 16 | .00048 | 34.6 |
| 180 | 30 | N | 36 | .00048 | 14.0 |
| 181 | 30 | N | 32 | .00048 | 12.1 |
| 182 | 60 | N | 19 | .00049 | |
| 183 | 40 | N | 31 | .00050 | 15.0 |
| 184 | 40 | N | 28 | .00050 | 13.2 |
| 185 | 30 | P | 31 | .00051 | |
| 186 | 50 | P | 22 | .00056 | |
| 187 | 60 | P | 18 | .00057 | |
| 188 | 30 | P | 30 | .00058 | |
| 189 | 30 | N | 33 | .00060 | |
| 190 | 40 | P | 28 | .00063 | 17.9 |
| 191 | 60 | N | 18 | .00063 | 16.1 |
| 192 | 40 | P | 27 | .00072 | 17.0 |
| 193 | 50 | N | 24 | .00072 | 15.0 |
| 194 | 50 | N | 22 | .00075 | 13.3 |
| 195 | 40 | N | 27 | .00075 | 12.5 |
| 196 | 40 | N | 25 | .00075 | 11.1 |
| 197 | 30 | N | 28 | .00078 | |
| 198 | 30 | P | 29 | .00080 | 15.1 |
| 199 | 60 | N | 17 | .00080 | 15.0 |
| 200 | 40 | P | 26 | .00081 | 16.1 |
| 201 | 30 | N | 30 | .00081 | 10.8 |
| 202 | 50 | N | 23 | .00083 | |
| 203 | 50 | P | 21 | .00086 | |
| 204 | 30 | P | 28 | .00090 | |
| 205 | 30 | N | 31 | .00091 | |
| 206 | 30 | N | 26 | .00098 | |
| 207 | 30 | P | 27 | .00101 | |
| 208 | 50 | N | 20 | .00104 | |
| 209 | 40 | N | 26 | .00106 | |

Table 6. Cutting Sequence (Continued)

| Sequence | Block Description SI | P or N | Age | Incremental Change in ROR ROR Gain | Yield (Shown Only for Ties in ICROR) |
|---|---|---|---|---|---|
| 210 | 70 | P | 15 | .00107 | |
| 211 | 40 | P | 25 | .00111 | 15.1 |
| 212 | 50 | N | 21 | .00111 | 12.4 |
| 213 | 30 | N | 29 | .00111 | 10.1 |
| 214 | 30 | N | 27 | .00112 | |
| 215 | 60 | P | 17 | .00120 | |
| 216 | 50 | N | 19 | .00121 | |
| 217 | 50 | P | 20 | .00124 | |
| 218 | 40 | N | 23 | .00125 | |
| 219 | 30 | N | 24 | .00126 | |
| 220 | 40 | P | 24 | .00127 | |
| 221 | 60 | N | 16 | .00130 | |
| 222 | 40 | N | 24 | .00133 | |
| 223 | 30 | P | 26 | .00134 | |
| 224 | 40 | N | 21 | .00135 | |
| 225 | 40 | P | 23 | .00147 | |
| 226 | 30 | P | 25 | .00153 | |
| 227 | 60 | P | 16 | .00159 | |
| 228 | 60 | N | 15 | .00164 | |
| 229 | 30 | N | 25 | .00166 | |
| 230 | 40 | P | 22 | .00168 | |
| 231 | 50 | P | 19 | .00171 | |
| 232 | 40 | N | 22 | .00172 | |
| 233 | 30 | P | 24 | .00174 | |
| 234 | 40 | N | 20 | .00189 | |
| 235 | 50 | N | 17 | .00193 | |
| 236 | 40 | P | 21 | .00196 | |
| 237 | 30 | P | 23 | .00199 | |
| 238 | 30 | N | 22 | .00201 | |
| 239 | 50 | P | 18 | .00208 | 14.4 |
| 240 | 30 | N | 23 | .00208 | 6.6 |
| 241 | 30 | N | 20 | .00221 | |
| 242 | 50 | N | 18 | .00225 | |
| 243 | 30 | P | 22 | .00228 | |
| 244 | 70 | N | 11 | .00232 | |
| 245 | 70 | P | 14 | .00251 | |
| 246 | 40 | N | 19 | .00256 | |
| 247 | 40 | P | 20 | .00257 | 10.0 |
| 248 | 40 | N | 18 | .00257 | 6.0 |
| 249 | 60 | P | 15 | .00263 | |
| 250 | 30 | N | 21 | .00270 | |

Table 6. Cutting Sequence (Continued)

| Sequence | Block Description SI | P or N | Age | Incremental Change in ROR ROR Gain | Yield (Shown Only for Ties in ICROR) |
|---|---|---|---|---|---|
| 251 | 50 | P | 17 | .00281 | |
| 252 | 50 | N | 16 | .00293 | |
| 253 | 30 | N | 18 | .00294 | |
| 254 | 30 | P | 21 | .00298 | |
| 255 | 30 | N | 19 | .00302 | |
| 256 | 40 | P | 19 | .00303 | |
| 257 | 40 | N | 16 | .00306 | |
| 258 | 50 | N | 15 | .00308 | |
| 259 | 60 | N | 14 | .00318 | |
| 260 | 30 | N | 17 | .00338 | |
| 261 | 50 | P | 16 | .00346 | |
| 262 | 60 | P | 14 | .00348 | 17.3 |
| 263 | 30 | P | 20 | .00348 | 7.0 |
| 264 | 40 | N | 17 | .00348 | 5.2 |
| 265 | 40 | P | 18 | .00359 | |
| 266 | 30 | P | 19 | .00409 | |
| 267 | 40 | P | 17 | .00429 | |
| 268 | 60 | N | 13 | .00450 | |
| 269 | 30 | N | 16 | .00461 | |
| 270 | 50 | P | 15 | .00465 | |
| 271 | 30 | N | 15 | .00468 | |
| 272 | 40 | N | 15 | .00479 | |
| 273 | 70 | P | 13 | .00516 | |
| 274 | 50 | N | 14 | .00529 | |
| 275 | 30 | P | 18 | .00535 | |
| 276 | 40 | P | 16 | .00563 | |
| 277 | 60 | P | 13 | .00567 | |
| 278 | 50 | P | 14 | .00583 | |
| 279 | 30 | P | 17 | .00645 | |
| 280 | 30 | P | 16 | .00654 | |
| 281 | 70 | N | 10 | .00713 | |
| 282 | 40 | N | 14 | .00716 | |
| 283 | 50 | N | 13 | .00722 | |
| 284 | 40 | P | 14 | .00728 | |
| 285 | 60 | N | 12 | .00737 | |
| 286 | 50 | P | 13 | .00739 | |
| 287 | 40 | P | 15 | .00748 | |
| 288 | 70 | P | 12 | .00902 | |
| 289 | 60 | P | 12 | .00978 | |
| 290 | 70 | P | 11 | .01010 | |

Table 6. Cutting Sequence (Continued)

| Sequence | Block Description SI | P or N | Age | Incremental Change in ROR ROR Gain | Yield (Shown Only for Ties in ICROR) |
|---|---|---|---|---|---|
| 291 | 50 | P | 12 | .01078 | |
| 292 | 60 | N | 11 | .01175 | |
| 293 | 50 | N | 12 | .01295 | |
| 294 | 60 | P | 11 | .01318 | |
| 295 | 70 | P | 10 | .01326 | |
| 296 | 60 | P | 10 | .01811 | |
| 297 | 70 | N | 9 | .01841 | |
| 298 | 70 | P | 9 | .01897 | |
| 299 | 70 | P | 8 | .02073 | |
| 300 | 60 | N | 10 | .02217 | |
| 301 | 70 | N | 8 | .02828 | |

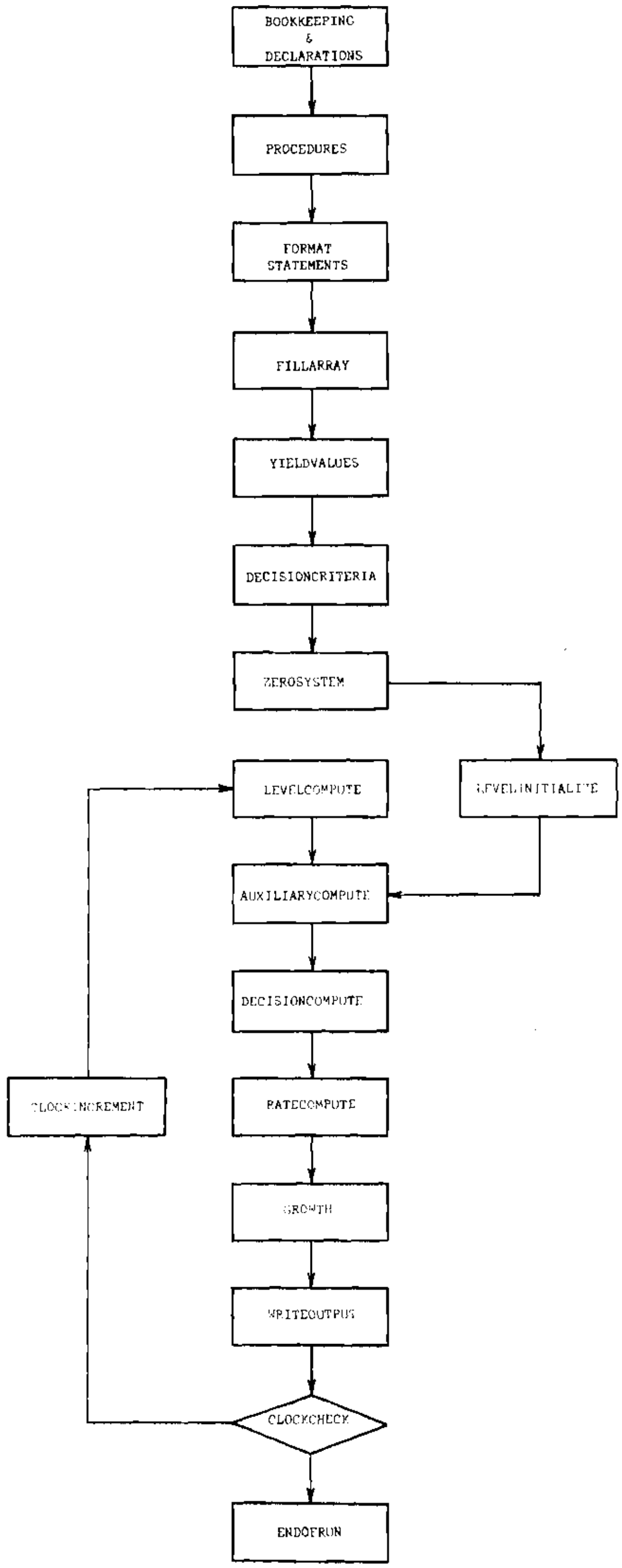


Figure 16. Computer Flow Diagram of the Forest Management Model

Procedures

The model is heavily procedure oriented. Numerous procedures are included which greatly simplify the writing of the actual model equations. Also, several procedures are included which were not actually used in this study but which might prove helpful in extensive experimentation with the model. The procedures used in this study are described as follows.

Real Procedure MAX. The MAX procedure provides an easy method of determining the maximum of two values. When called in the following manner:

MAX(A,B)

the procedure will yield the numerically greater value of A or B.

Real Procedure MIN. The MIN procedure operates in the same manner as the MAX procedure, however, will yield the numerically smaller of the two input values.

Real Procedure CLIP. The CLIP procedure operates much the same as the CLIP function in DYNAMO. The CLIP procedure is called as follows:

CLIP(H,L,N,C)

and will yield the following result:

$$CLIP = \begin{matrix} H \text{ if } N \geq C \\ L \text{ if } N < C \end{matrix}$$

Real Procedure RAMP. The RAMP procedure allows a variable to be increased by a constant amount each time period without the writing of a formal equation. Called in the following manner

RAMP(P,Q,V)

the procedure will yield the following result:

$$\text{RAMP} = \begin{cases} P + V & \text{if TIMEX} \geq Q \\ V & \text{if TIMEX} < Q \end{cases}$$

TIMEX - Timekeeping Function

Procedure READARRAY. The READARRAY procedure greatly simplifies the reading of data values into a one-dimensional array. Each time it is called, READARRAY will read 41 values into the array specified in the procedure call. The procedure reads only data cards coded in a particular way, thus allowing comment cards to be placed in the data deck.

Procedure READTWOARRAY. The READTWOARRAY procedure functions in the same manner as the READARRAY procedure, however it reads 41 data values into the first column if a two-dimensional array.

Real Procedure SUMMATION. The SUMMATION procedure provides an easy method of summing the values in an array. Called in the following manner,

SUMMATION(I,I1,I2,FUNCTION)

the procedure will increment the counter I from a low value of I1 to a high value of I2 while summing any FUNCTION containing the I subscript.

Procedure CUTDECISION. The CUTDECISION procedure was developed to increase the generality of the forest management model. It allows 20 cutting decision parameters to be set or changed with only one statement. That statement:

CUTDECISION(A,B,...,J)

assigns the ten values A through J and the ten values 1-A, 1-B, ..., 1-J in the following manner:

```
P3NLC[K]=A
P3NLS[K]=1-A
P3PLC[K]=B
P3PLS[K]=1-B
P4NLC[K]=C
P4NLS[K]=1-C
P4PLC[K]=D
P4PLS[K]=1-D
P5NLC[K]=E
P5NLS[K]=1-E
P5PLC[K]=F
P5PLS[K]=1-F
P6NLC[K]=G
P6NLS[K]=1-G
P6PLC[K]=H
P6PLS[K]=1-H
P7NLC[K]=I
P7NLS[K]=1-I
P7PLC[K]=J
P7PLS[K]=1-J
```

PXNLC(K) - Per Cent of Site Index X0 Natural Land to be Harvested in the Next Time Interval (K to L) Which is to be Clear Cut (Per Cent of Acres)

PXNLS(K) - Per Cent of Site Index X0 Natural Land to be Harvested in the Next Time Interval (K to L) Which is to be Selective Cut (Per Cent of Acres)

PXPLC(K) - Per Cent of Site Index X0 Plantation Land to be Harvested in the Next Time Interval (K to L) Which is to be Clear Cut (Per Cent of Acres)

PXPLS(K) - Per Cent of Site Index X0 Plantation Land to be Harvested in the Next Time Interval (K to L) Which is to be Selective Cut (Per Cent of Acres)

Procedure CUTRATE. The CUTRATE procedure forms the heart of the computations associated with the setting of cutting rates in accordance with the cutting sequence and cutting policy parameters. When called in the following manner:

```
CUTRATE(A)
```

the procedure sets the cutting rates for block A in the cutting sequence. The procedure operates as follows:

```
B=SI[A]
C=PORN[A]
D=AGE[A]
```

```
SI[A]    - The Site Index of Land in Block A of the Cutting Sequence.
           SI[A]=3,4,5,6, or 7
PORN[A] - The Status of Land in Block A of the Cutting Sequence
           PORN[A]=0 Represents Natural Land
           PORN[A]=1 Represents Plantation Land
AGE[A]   - The Age of the Stand in Block A of the Cutting Sequence
           AGE[A]=0 Through 41
```

Based on the values of B and C, the procedure switches to a set of equations which are appropriate for the site index and status of the land under consideration. Ten similar sets of equations are provided to allow for all possible combinations of site index and status.

Within a given set of equations, the procedure first determines whether there are any acres in the block under consideration. If there are none, the potential cut, clear cutting rate and selective cutting rate are set to zero. If there are acres in the block under consideration, the procedure determines the potential cut according to current cutting policy parameters, the cords to cut from the block under consideration to meet the remaining demand for wood, and the appropriate clear and selective cutting rates. A typical set of equations for site index 60 plantation land is as follows.

```
IF A6P[K,D] ≤ 0 THEN
BEGIN
   PCUT[K,A] = 0
   CC6PSD[K,D] = 0
   C6P[KL,D] = 0
   S6P[KL,D] = 0
   CREM[K,A] = CREM[K,A-1]
END
ELSE
BEGIN
   PCUT[K,A] = (P6PLC[K]) x (PC6PC[K,D])
          +    (P6PLS[K]) x (PC6PS[K,D])
   CREM[K,A] = CREM[K,A-1] - PCUT[K,A]
   CC6PSD[K,D] = CLIP(PCUT[K,A],CREM[K,A-1],
                       CREM[K,A],0)
   C6P[KL,D] = (CC6PSD[K,D]/PCUT[K,A]) x
               (P6PLC[K]) x (A6P[K,D])
```

```
   S6P[KL,D] = (CC6PSD[K,D]/PCUT[K,A]) x
               (P6PLS[K]) x (A6P[K,D])
   CREM[K,A] = MAX(CREM[K,A],0)
END
```

where the variables are defined as follows:

A6P[K,D] - Acres of Land of Site Index 60 in Plantation Status D Years Old (Acres)
PCUT[K,A] - Potential Cords Cut if the Entire Acreage in the Block Under Consideration (A) is Cut According to the Current Cutting Policy (Cords)
CC6PSD[K,D] - Cords to Cut from Site Index 60 Plantation Land D Years Old to Satisfy the Remaining Demand for Wood During the Next Time Interval (K to L) (Cords)
C6P[KL,D] - Clear Cutting Rate for Site Index 60 Plantation Land D Years Old for the Next Time Interval (K to L) (Acres/Year)
S6P[KL,D] - Selective Cutting Rate for Site Index 60 Plantation Land D Years Old for the Next Time Interval (K to L) (Acres/Year)
CREM[K,A] - Cords Remaining to be Cut During the Next Time Interval (K to L) if All Acreage in the Block Under Consideration (A) is Cut According to the Current Cutting Policy (Cords)
P6PLC[K] - Per Cent of Site Index 60 Plantation Land to be Harvested in the Next Time Interval (K to L) which is to be Clear Cut (Per Cent of Acres)
PC6PC[K,D] - Potential Cords if All Acres in Site Index 60 Plantation Status D Years Old were Clear Cut (Cords)
P6PLS[K] - Per Cent of Site Index 60 Plantation Land to be Harvested in the Next Time Interval (K to L) which is to be Selective Cut (Per Cent of Acres)
PC6PS[K,D] - Potential Cords if All Acres in Site Index 60 Plantation Status D Years Old Were Selective Cut (Cords)

Note that the CUTRATE procedure utilizes the number of cords remaining to be cut after block A-1 was cut (CREM[K,A-1]) in determining the cutting rates for block A. Also, the number of cords remaining to be cut after cutting block A (CREM[K,A]) is set to a minimum value of zero to insure that a negative number of cords to be cut is not attempted in block A + 1. Once the required number of cords to satisfy demand is cut, CREM[K,A] is set to zero and further cutting is inhibited. A flow diagram of the CUTRATE computations for site index 60 plantation land Z years old for which the number of acres is positive is shown in Figure 17. Reference to the Abbreviated Flow Diagram of the Forest Management Model (Figure 15) will show how the CUTRATE computations fit into the overall model structure.

Procedure PLANTDECISION. The PLANTDECISION procedure allows five planting decision parameters to be set or changed with only one statement. That statement

```
PLANTDECISION(A,B,C,D,E)
```

assigns the five decimal values A through E in the following manner:

```
PR30[KL]=(A)(ACL3P[K])
PR40[KL]=(B)(ACL4P[K])
PR50[KL]=(C)(ACL5P[K])
PR60[KL]=(D)(ACL6P[K])
PR70[KL]=(E)(ACL7P[K])
```

PRX0[KL] - Planting Rate (Plantation Land) for Site Index X0 Land for the Next Time Interval (K to L) (Acres/Year)
ACLXP[K] - Acres of Cleared Land of Site Index X0 to be Planted in Plantation Status at Some Time in the Future (Acres)
A,B,C,D,E - Values Representing Per Cent of Land in the Given Category to be Planted During the Next Time Interval (K to L) (Per Cent)

## Format Statements

This segment of the program consists of the various format statements required to read data and print tabular results. The program allows two input data files. One is a tape file for large blocks of data which need not be changed often. The other is a card file and consists of those variables which might be varied frequently in model experiments.

## Fillarray

The FILLARRAY segment of the program consists of three statements required to fill arrays with cutting sequence data. The statement

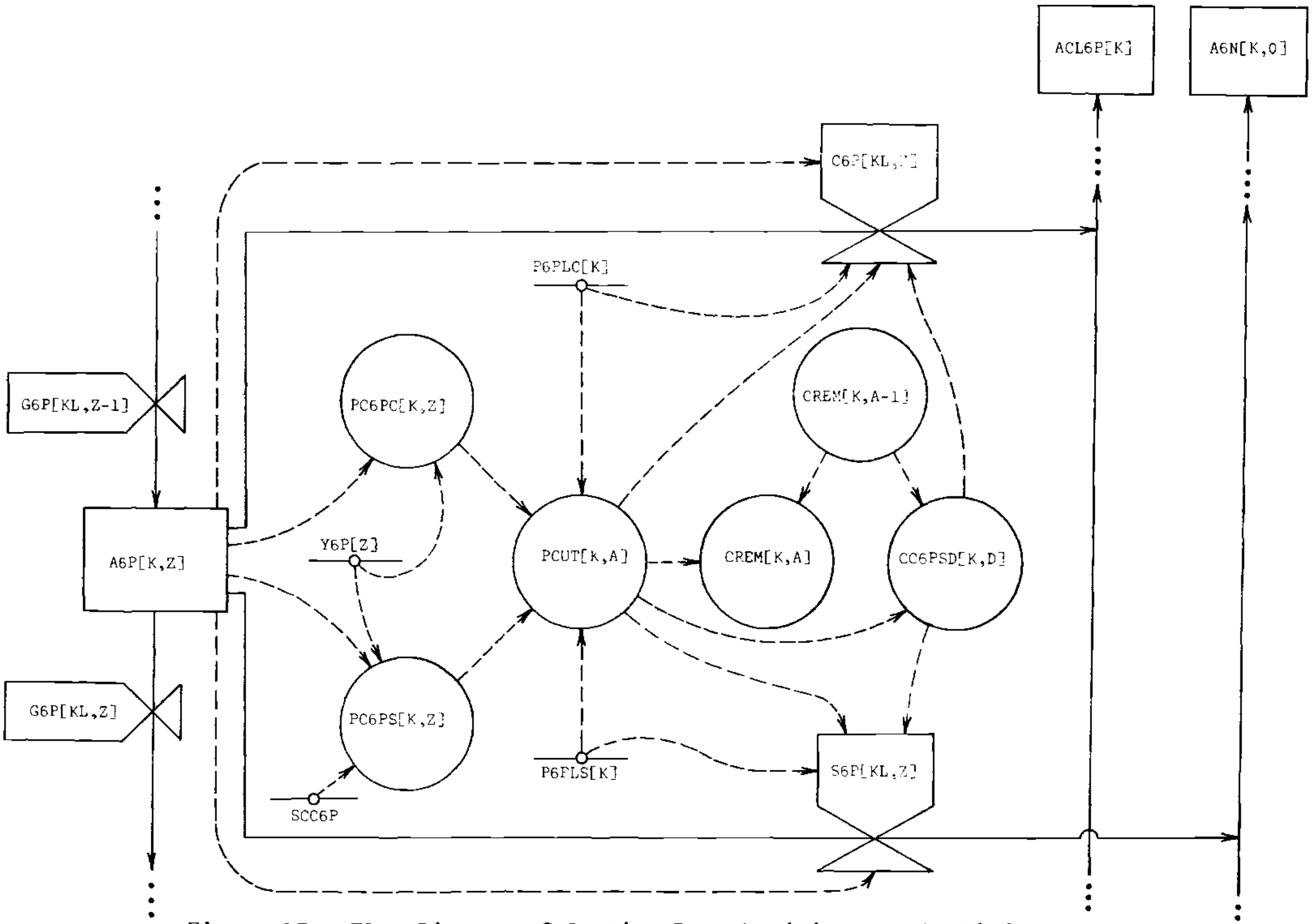


Figure 17. Flow Diagram of Cutting Rate Decisions as Applied to Site Index 60 Plantation Land Z Years Old

FILL SI[*] with ...

fills a one-dimensional array with the first digit of the site index of the 301 blocks in the cutting sequence such that

SI[A] is the site index of the A'th block
in the cutting sequence.

In the same manner, the statement

FILL PORN[*] with ...

fills an array with the status of the 301 blocks in the cutting sequence where

PORN[A]=0 Represents Natural Land
PRON[A]=1 Represents Plantation Land

Lastly, the statement

FILL AGE[*] with ...

fills an array with the stand ages of the 301 blocks in the cutting sequence.

Yieldvalues

The YIELDVALUES segment of the program utilizes the READARRAY procedure to read yield coefficients into one-dimensional arrays. The READARRAY procedure is called ten times in the following manner:

READARRAY [YXN]
READARRAY [YXP]

XYN - Yield of Land of Site Index X0 in Natural Status (Cords/Acre).
X0 is 30,40,50,60 and 70.
YXP - Yield of Land of Site Index X0 in Plantation Status (Cords/Acre).
X0 is 30,40,50,60, and 70.

With each call, the READARRAY procedure reads 41 yield values (representing 41 stand ages) into the appropriate yield array.

Decisioncriteria

This segment of the program consists of two assignment statements and 11 read statements. The assignment statements

```
LENGTH=100
DT=1
```

specify the length of the simulation run (100 years), and the solution time interval (one year).

The first read statement determines values for the following parameters

```
CONCON1
DEMCON
```

CONCON1 - Control Constant 1 (Dimensionless): Determines Whether Demand Pattern is Constant or Ramp; CONCON1=0 Represents Constant Demand, CONCON1=1 Represents Ramp Demand

DEMCON - Demand Constant (Cords/Year)

The other ten read statements establish values for Selective Cutting Coefficients for the ten forest management treatments in the model. A selective cutting coefficient is defined as the per cent cut reflecting a selective policy and is expressed in "per cent of cords."

Zerosystem

The ZEROSYSTEM segment of the program establishes the timekeeping and subscripting variables used in the simulation run as follows:

```
TIMEX=0
J=TIMEX-1
K=TIMEX
L=TIMEX+1
JK=TIMEX-1
KL=TIMEX
```

TIMEX - Timekeeping Variable

J,K,L,JK,KL - Subscripting Variables

Levelinitialize

The LEVELINITIALIZE segment of the program establishes the initial values of demand (DEMAND[0]) and the demand ramp increase (DEMRAM[0]) and reads the initial values of levels (number of acres of land in the various blocks in the model at TIMEX=0). The number of acres of land in the five site indices is read directly from the card input file. The other 410 levels are read from the tape input file through the use of the READTOWARRAY procedure. The appropriate statements are:

```
READTWOARRAY(AXN)
READTWOARRAY(AXP)
```

AXN - Acres of Land of Site Index X0 in Natural Status (Acres). X0 is 30,40,50,60, and 70.
AXP - Acres of Land of Site Index X0 in Plantation Status (Acres). X0 is 30,40,50,60, and 70.

In determining the numerical values of initial values of levels, it was assumed that the total forest resource under consideration amounts to 100,000 acres. It was also assumed that 25 per cent of this acreage (25,000 acres) is already in plantation status and the rest in natural growth status.

In order to approximate real-world conditions, the work of Bennett, McGee, and Clutter (30) was used in determining the initial distribution of plantation land by age and site index. Assuming that 1000 acres of plantation land are initially in a cleared condition and the other 24,000 distributed among the various stand ages, and using the site index distributions reported by Bennett, McGee, and Clutter, the values shown in Table 7 were obtained.

Table 7. Distribution of Plantation Land by Site Index

| Site Index | Acres of Cleared Land | Acres of Planted Land |
|---|---|---|
| 30 | 7 | 162 |
| 40 | 27 | 648 |
| 50 | 78 | 1,865 |
| 60 | 469 | 11,271 |
| 70 | 419 | 10,054 |
| TOTAL | 1,000 | 24,000 |

The distribution of sample plots by age as reported by Bennett, McGee, and Clutter was not sufficient for the forest management model since stand ages under ten years old were not reported. However, the general form of the Bennett, McGee, and Clutter age distributions by site index were used. The resulting initial age distributions used in the forest management model are shown in Figures 18 through 22.

For natural growth land, no data were available which depicted distributions by age or site index. The assumed distribution of natural growth land by site index is shown in Figure 23. Table 8 shows the resultant acreage by site index.

Within each site index a uniform distribution of ages (rounded to integer values) was assumed. Tabular values of all initial conditions are shown in Appendix E.

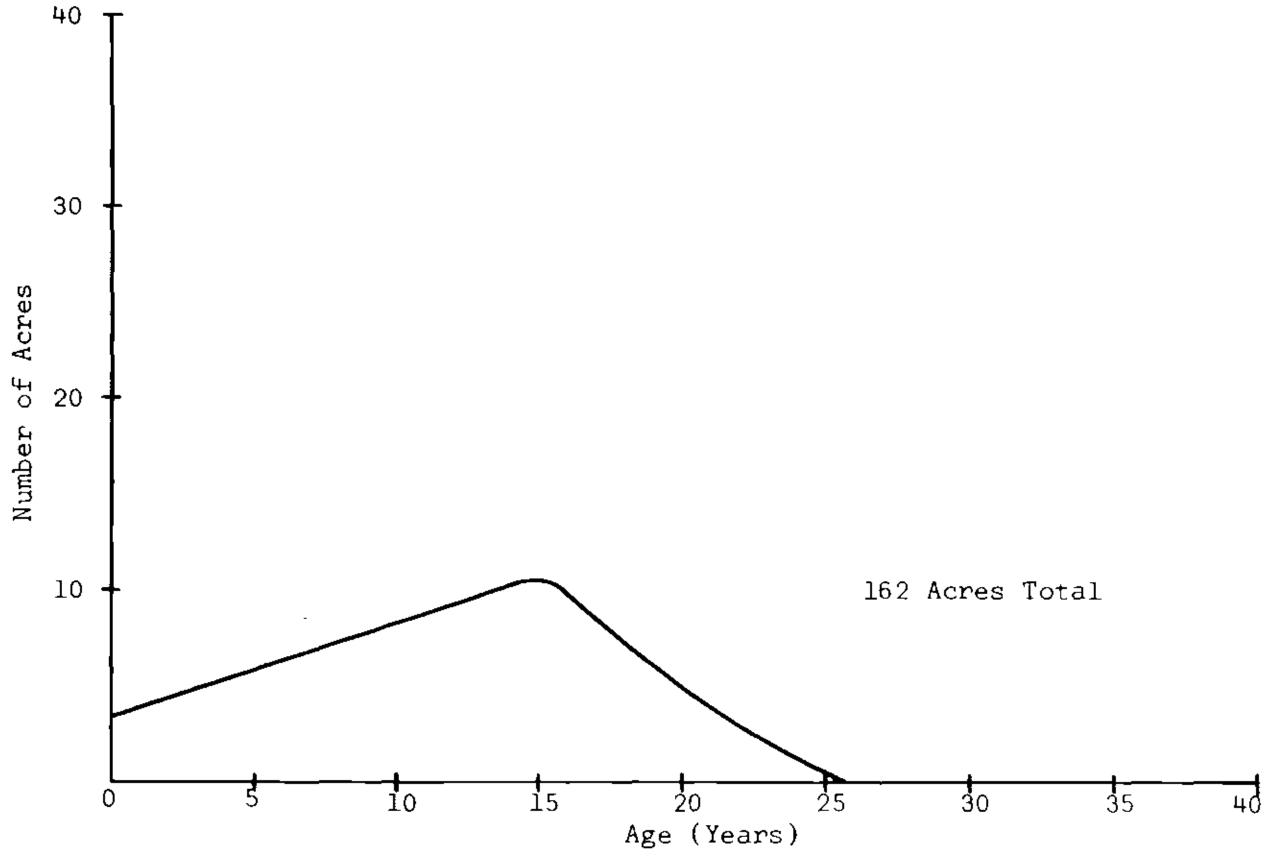


Figure 18. Initial Age Distribution for Site Index 30 Plantation Land

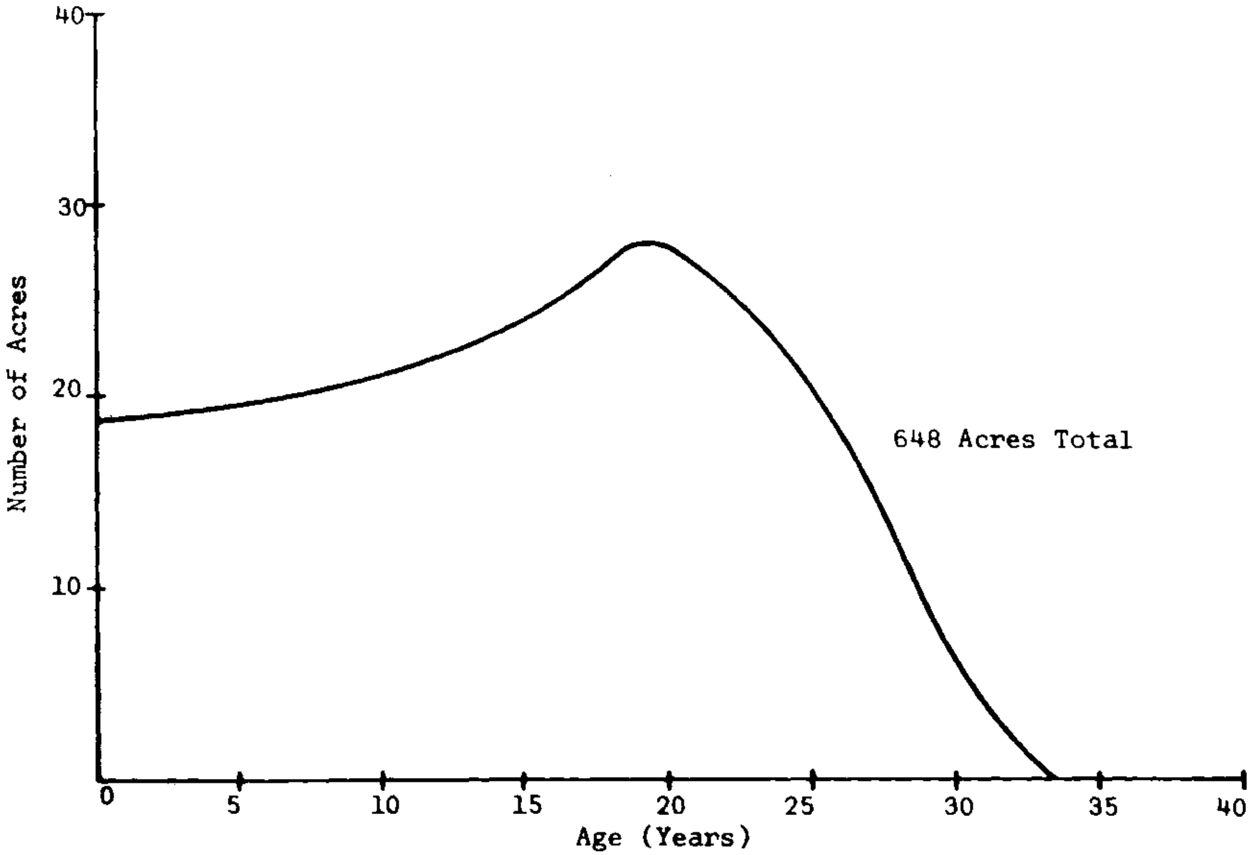


**Figure** 19. Initial **Age** Distribution for Site Index 40 Plantation Land

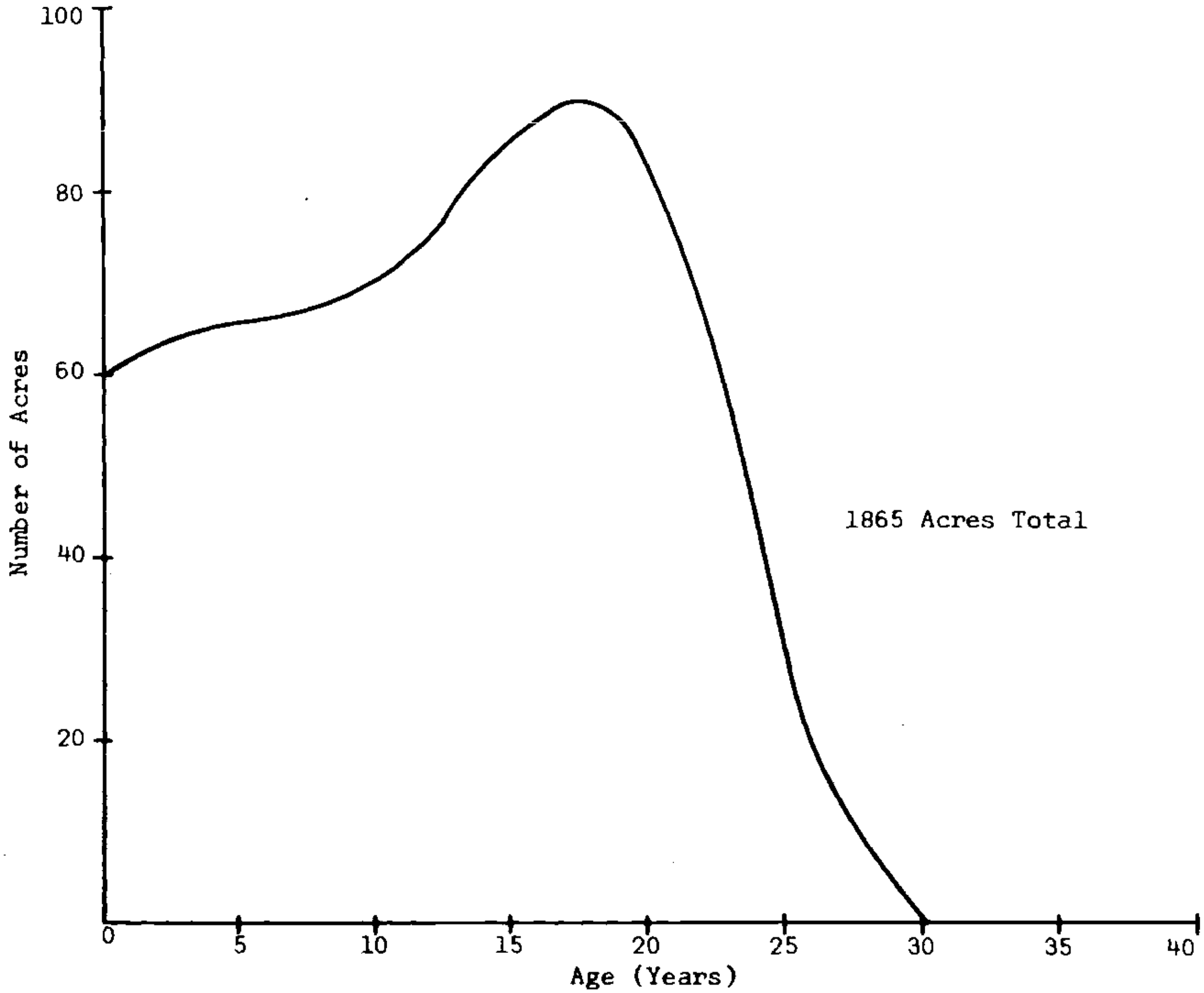


Figure 20. Initial Age Distribution for Site Index 50 Plantation Land

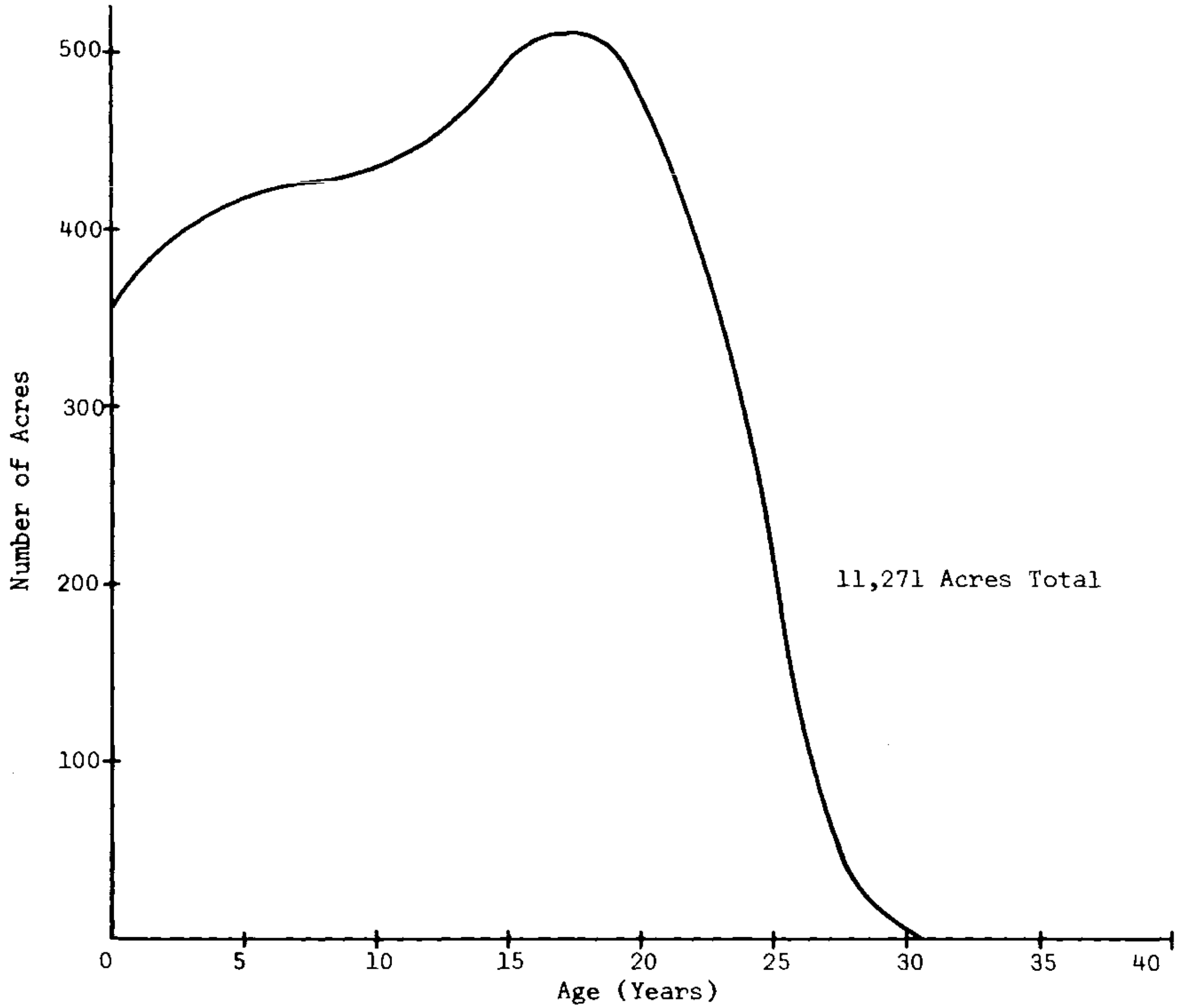


Figure 21. Initial Age Distribution for Site Index 60 Plantation Land

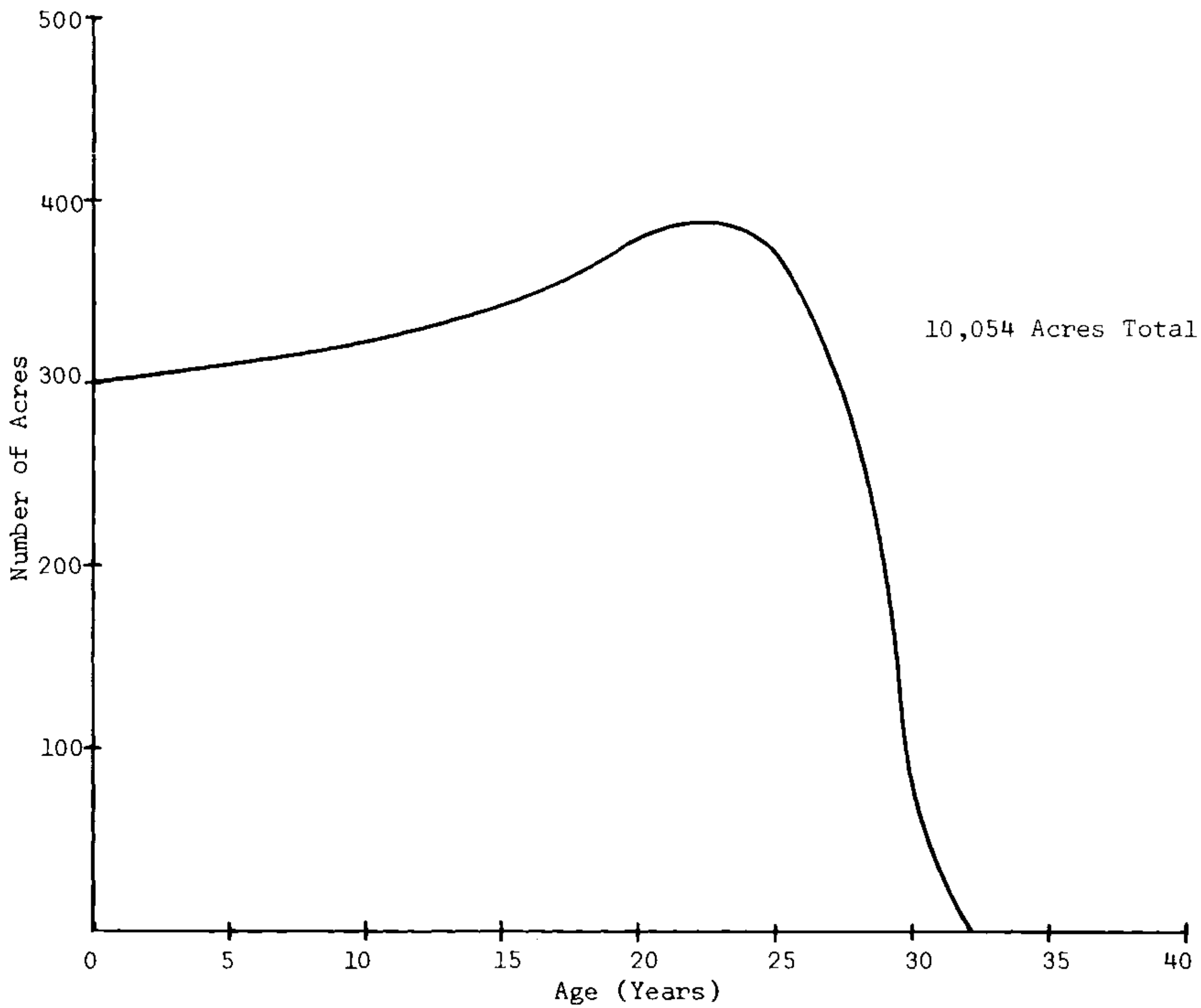


Figure 22. Initial Age Distribution for Site Index 70 Plantation Land

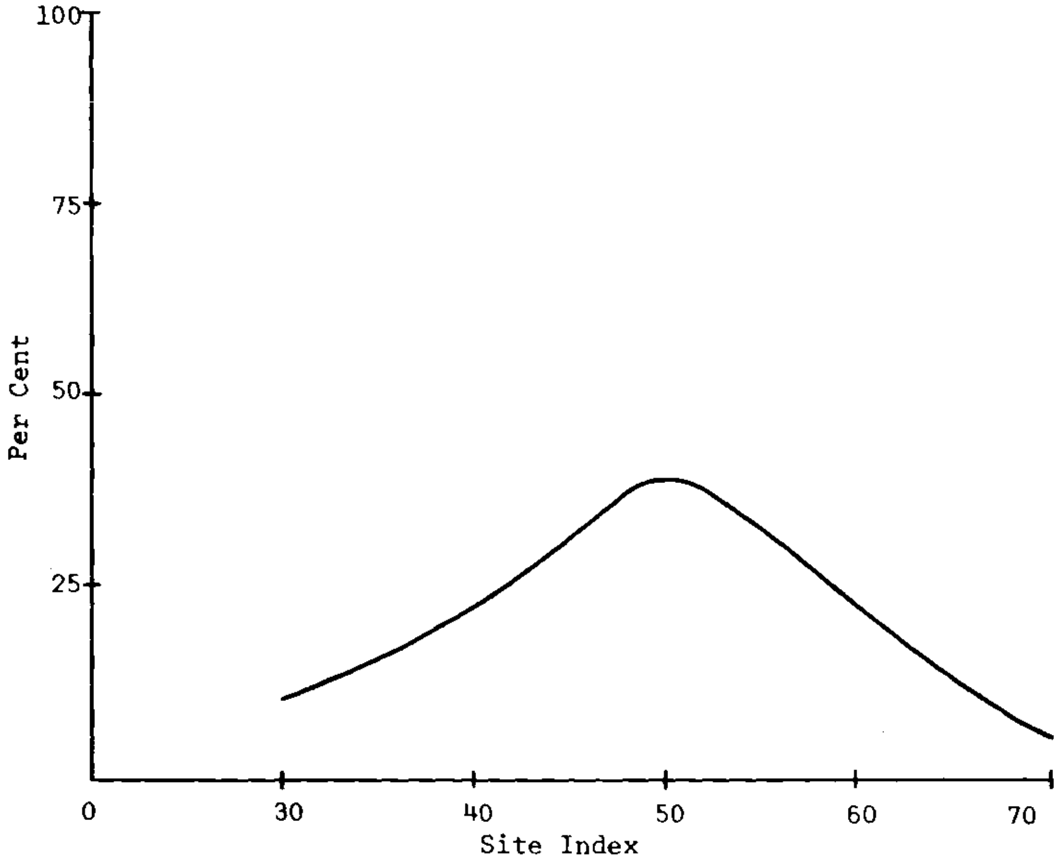


Figure 23. Initial Distribution of Natural Growth Land by Site Index

Table 8. Distribution of Natural Growth Land by Site Index

| Site Index | Per Cent of Land | Acreage |
|---|---|---|
| 30 | 10 | 7,500 |
| 40 | 22.5 | 16,875 |
| 50 | 40 | 30,000 |
| 60 | 22.5 | 16,875 |
| 70 | 5 | 3,750 |
| TOTAL | 100 | 75,000 |

Levelcompute

For TIMEX > 0, the LEVELCOMPUTE segment of the program is activated in each solution interval during the simulation run. The function of the LEVELCOMPUTE segment is to recalculate the values of all levels in the model at the beginning of each time period.

The first levels calculated represent the demand function for the next time interval.

```
DEMRAM[K]=RAMP(1000,0,DEMRAM[J])
DEMAND[K]=DEMCON+(CONCON1)x(DEMRAM[K])
```

DEMRAM - Demand Ramp Increase (Cords/Year)
DEMAND - Demand for Pulpwood for the Next Time Interval (K to L) (Cords/Year)
DEMCON - Demand Constant (Cords/Year)
CONCON1 - Control Constant One (Dimensionless)

In order to recalculate levels of acres, 20 equations (four for each site index) are required to sum the number of acres clear cut and selective cut in each of the ten forest management treatments during the preceding time interval (J to K). These equations utilize the SUMMATION procedure and are formulated in the following manner:

```
AXNCC[K]=SUMMATION(Z,0,41,CXN[JK,Z])
AXNSC[K]=SUMMATION(Z,0,41,SXN[JK,Z])
AXPCC[K]=SUMMATION(Z,0,41,CXP[JK,Z])
AXPSC[K]=SUMMATION(Z,0,41,SXP[JK,Z])
```

AXNCC(K) - Acres of Site Index X0 Natural Growth Land Clear Cut During the Preceding Time Interval (J to K) (Acres)
CXN(JK,Z) - Clear Cutting Rate for Site Index X0 Natural Growth Land During the Preceding Time Interval (J to K) (Acres/Year)
AXNSC(K) - Acres of Site Index X0 Natural Growth Land Selective Cut During the Preceding Time Interval (J to K) (Acres)
SXN(JK,Z) - Selective Cutting Rate for Site Index X0 Natural Growth Land During the Preceding Time Interval (J to K) (Acres/Year)
AXPCC(K) - Acres of Site Index X0 Plantation Land Clear Cut During the Preceding Time Interval (J to K) (Acres)
CXP(JK,Z) - Clear Cutting Rate for Site Index X0 Plantation Land During the Preceding Time Interval (J to K) (Acres/Year)
AXPSC(K) - Acres of Site Index X0 Plantation Land Selective Cut During the Preceding Time Interval (J to K) (Acres)
SCP(JK,Z) - Selective Cutting Rate for Site Index X0 Plantation Land During the Preceding Time Interval (J to K) (Acres/Year)

Note that the SUMMATION procedure is used to sum the appropriate cutting rates for the preceding time period over the entire range of stand ages.

The level of land in natural status zero years old in each of the site indices is merely the sum of the acres selective cut in that site index during the preceding year. The general form of the five equations required for this purpose is as follows:

```
AXN[K,0]=AXPSC[K]+AXNSC[K]
```

AXN[K,0] - Acres of Land of Site Index X0 in Natural Growth Status Zero Years Old (Acres)
AXPSC[K] - Acres of Site Index X0 Plantation Land Selective Cut During the Preceding Time Interval (J to K) (Acres)
AXNSC[K] - Acres of Site Index X0 Natural Growth Land Selective Cut During the Preceding Time Interval (J to K) (Acres)

The acres of cleared land in each site index is formulated as a function of the number of acres of cleared land at the previous point in time, the number of acres newly clear cut, and the number of acres planted during the preceding time interval. The general equation is as follows.

ACLXP[K]=ACLXP[J]+AXPCC[K]+AXNCC[K]-PRXO[JK]

ACLXP[K] - Acres of Cleared Land of Site Index X0 to be Planted in Plantation Status at Some Time in the Future (Acres)
AXPCC[K] - Acres of Site Index X0 Plantation Land Clear Cut During the Preceding Time Interval (J to K) (Acres)
AXNCC[K] - Acres of Site Index X0 Natural Growth Land Clear Cut During the Preceding Time Interval (J to K) (Acres)
PRXO[JK] - Planting Rate for Site Index X0 Cleared Land for the Preceding Time Interval (J to K) (Acres/Year)

The number of acres of zero-year old plantation land in each site index is equal to the number of acres that were planted during the preceding time interval. The general equation is,

AXP[K,0]=PRXO[JK]

AXP[K,0] - Acres of Land of Site Index X0 in Plantation Status Zero Years Old (Acres)
PRXO[JK] - Planting Rate for Site Index X0 Cleared Land During the Preceding Time Interval (J to K) (Acres/Year)

The number of acres of land of stand age Z (where Z=1 through 40) for all ten forest management treatments is equal to the number of acres of stand age Z-1 which were not scheduled for cutting during the preceding time interval. As will be seen later, this is defined as a growth rate (in acres). The general equations are:

AXN[K,Z]=GXN[JK,Z-1]
AXP[K,Z]=GXP[JK,Z-1]

AXN[K,Z] - Acres of Land of Site Index X0 in Natural Growth Status Z Years Old (Acres)
GXN[JK,Z-1] - Growth Rate for Site Index X0 Natural Growth Land Z-1 Years Old During the Preceding Time Interval (J to K) (Acres/Year)
AXP[K,Z] - Acres of Land of Site Index X0 in Plantation Status Z Years Old (Acres)

GXP[JK,Z-1] - Growth Rate for Site Index X0 Plantation Land Z-1 Years Old During the Preceding Time Interval (J to K) (Acres/Year)

Lastly, the number of acres in the ten forest management treatments which are 41 years old is formulated as a function of the number of acres in the same block one time period previous, the growth rate for 40-year-old stands during the preceding time interval and the cutting rates for the block under consideration during the previous time interval. The general equations for natural and plantation lands are as follows:

AXN[K,41]=AXN[J,41]+GXN[JK,40]-CXN[JK,41]-SXN[JK,41]
AXP[K,41]=AXP[J,41]+GXP[JK,40]-CXP[JK,41]-SXP[JK,41]

AXN[K,41] - Acres of Land of Site Index X0 in Natural Growth Status 41 Years Old (Acres)
GXN[JK,40] - Growth Rate for Site Index X0 Natural Growth Land 40 Years Old During the Preceding Time Interval (J to K) (Acres/Year)
CXN[JK,41] - Clear Cutting Rate for Site Index X0 Natural Growth Land 41 Years Old During the Preceding Time Interval (J to K) (Acres/Year)
SXN[JK,41] - Selective Cutting Rate for Site Index X0 Natural Growth Land 41 Years Old During the Preceding Time Interval (J to K) (Acres/Year)
AXP[K,41] - Acres of Land of Site Index X0 in Plantation Status 41 Years Old (Acres)
GXP[JK,40] - Growth Rate for Site Index X0 Plantation Land 40 Years Old During the Preceding Time Interval (J to K) (Acres/Year)
CXP[JK,41] - Clear Cutting Rate for Site Index X0 Plantation Land 41 Years Old During the Preceding Time Interval (J to K) (Acres/Year)
SXP[JK,41] - Selective Cutting Rate for Site Index X0 Plantation Land 41 Years Old During the Preceding Time Interval (J to K) (Acres/Year)

Auxiliarycompute

The AUXILIARYCOMPUTE segment of the program determines the potential cords cut if different forest management treatments were to be clear cut or selective cut during the next time interval. All equations are imbedded in a loop which calculates values for the entire range of stand ages (Z=0 to 41). The general equations are formulated as follows:

```
PCXNC[K,Z] = (AXN[K,Z]) x (YXN[Z])
PCXNS[K,Z] = (AXN[K,Z]) x (YXN[Z]) x (SCCXN)
PCXPC[K,Z] = (AXP[K,Z]) x (YXP[Z])
PCXPS[K,Z] = (AXP[K,Z]) x (YXP[Z]) x (SCCXP)
```

| | |
|---|---|
| PCXNC[K,Z] | - Potential Cords if All Acres in Site Index X0 Natural Growth Status Z Years Old were Clear Cut (Cords) |
| AXN[K,Z] | - Acres of Land of Site Index X0 in Natural Growth Status Z Years Old (Acres) |
| YXN[Z] | - Yield of Land of Site Index X0 in Natural Growth Status Z Years Old (Cords/Acre) |
| PCXNS[K,Z] | - Potential Cords if all Acres in Site Index X0 Natural Growth Status Z Years Old were Selective Cut (Cords) |
| SCCXN | - Selective Cutting Coefficient for Site Index X0 Natural Growth Land (Per Cent of Cords) |
| PCXPC[K,Z] | - Potential Cords if all Acres of Site Index X0 Plantation Land Z Years Old were Clear Cut (Cords) |
| AXP[K,Z] | - Acres of Land of Site Index X0 in Plantation Status Z Years Old (Acres) |
| YXP[Z] | - Yield of Land of Site Index X0 in Plantation Status Z Years Old (Cords/Acre) |
| PCXPS[K,Z] | - Potential Cords if All Acres of Site Index X0 Plantation Land Z Years Old were Selective Cut (Cords) |
| SCCXP | - Selective Cutting Coefficient for Site Index X0 Plantation Land (Per Cent of Cords) |

Decisioncompute

The DECISIONCOMPUTE segment of the program provides the mechanism for changing forest management policies or speed of response to the current condition of the forest resource. Two primary variables are used in determining policy decisions to be made.

Average demand for pulp (AVDEM[K]) is computed on the basis of the current and past levels of DEMAND[K].

Total Cords on the Stump (TCS[K]) is formulated as the sum of all cords obtained if all acres in the forest were clear cut. The SUMMATION procedure is used as follows:

```
TCS[K] = SUMMATION(Z,0,41,PC3NC[K,Z] + PC4NC[K,Z] +
         PC5NC[K,Z] + PC6NC[K,Z] + PC7NC[K,Z] + PC3PC[K,Z] +
         PC4PC[K,Z] + PC5PC[K,Z] + PC6PC[K,Z] + PC7PC[K,Z])
```

TCS[K] - Total Cords on the Stump (Cords)
PCXNC[K,Z] - Potential Cords if all Acres of Site Index X0 Land in Natural Growth Status Z Years Old were Clear Cut (Cords)
PCXPC[K,Z] - Potential Cords if all Acres of Site Index X0 Land in Plantation Status Z Years Old were Clear Cut (Cords)

A comparison is then made between AVDEM[K] and TCS[K]. Through a set of numerical coefficients which reflect the speed of response to changing forest conditions, the program then switches to one of several Decision Labels. A total of six Decision Labels is provided to allow a graduated response to changing forest resource conditions.

Within each Decision Label, a single statement (employing the CUTDECISION procedure) sets 20 coefficients representing the per cent of land in each of the ten forest management treatments to be clear and selective cut during the next time interval.

Ratecompute

The RATECOMPUTE segment of the program establishes all cutting rates and planting rates in the model.

The construct:

```
FOR I = 1 STEP 1 UNTIL 301 DO
CUTRATE(I)
```

calls the CUTRATE procedure 301 times in succession. As previously discussed, the CUTRATE procedure evaluates the clear and selective cutting rates for the block under consideration according to a set of decision policies as determined by the DECISIONCOMPUTE segment of the program. In calling the CUTRATE procedure 301 times, all cutting rates for the predetermined cutting sequence are evaluated. Cutting rates for the 109 blocks for which harvesting is prohibited (due to a negative value of rate-of-return) are set to zero through the use of simple loop-nested assignment statements.

Planting rates in the model are established in much the same way as cutting decision parameters were. A comparison is again made between Average Demand (AVDEM[K]) and Total Cords on the Stump (TCS[K]). The same set of numerical coefficients reflecting the speed of response to changing forest resource conditions is used to switch the program to one of six Planting Labels.

Within each Planting Label, the PLANTDECISION procedure is used to set the planting rates for the next time interval for each of the five site indices.

Growth

The GROWTH segment of the program determines the number of acres in each block which will be allowed to grow during the next time interval. The growth rate for a particular block is formulated as the difference between the number of acres in the block and the number of acres in the block which have been scheduled to be cut during the next time interval. The general equations are as follows:

GXN[KL,Z] = AXN[K,Z] - CXN[KL,Z] - SXN[KL,Z]
GXP[KL,Z] = AXP[K,Z] - CXP[KL,Z] - SXP[KL,Z]

GXN[KL,Z] - Growth Rate for Site Index X0 Natural Growth Land Z Years Old (Acres/Year)
AXN[K,Z] - Acres of Land of Site Index X0 in Natural Growth Status Z Years Old (Acres)
CXN[KL,Z] - Clear Cutting Rate for Site Index X0 Natural Growth Land Z Years Old (Acres/Year)

SXN[KL,Z] - Selective Cutting Rate for Site Index X0 Natural Growth Land Z Years Old (Acres/Year)

GXP[KL,Z] - Growth Rate for Site Index X0 Plantation Land Z Years Old (Acres/Year)

AXP[K,Z] - Acres of Land of Site Index X0 in Plantation Status Z Years Old (Acres)

CXP[KL,Z] - Clear Cutting Rate for Site Index X0 Plantation Land Z Years Old (Acres/Year)

SXP[KL,Z] - Selective Cutting Rate for Site Index X0 Plantation Land Z Years Old (Acres/Year)

Writeoutput

The WRITEOUTPUT segment of the program consists of the statements necessary to print desired tabular output at the end of each year of the simulation. In this study the following significant variables were printed for each time period.

Demand Ramp (DEMRAM)
Demand (DEMAND)
Average Demand (AVDEM)
Total Cords on the Stump (TCS)
Acres Cut (J to K)
Acres to Cut (K to L) (ACUT)
Cords Cut (K to L) (CCUT)
Cords Per Acre (K to L) (CPA)
Unsatisfied Demand (K to L) (USD)
Values of Levels of Acres for all Forest Management Treatments and Stand Ages
Values of Cutting Rates for all Forest Management Treatments and Stand Ages

A sample tabular output of the forest management model is shown in Appendix F.

Clockcheck

The CLOCKCHECK segment tests the timekeeping function to see if the simulation run has been completed. If not, control is passed to the CLOCKINCREMENT segment. If the simulation is complete, control is passed to ENDOFRUN.

Clockincrement

The CLOCKINCREMENT segment increments all timekeeping and subscripting values by one as follows:

```
TIMEX = TIMEX + DT
J = J + 1
K = K + 1
L = L + 1
JK = JK + 1
KL = KL + 1
```

TIMEX - Timekeeping Variable
J,K,L,JK,KL - Subscripting Variables
DT - Interval Between Computations (1 Year)

Control is then passed to LEVELCOMPUTE for the commencement of computations for another time period.

Endofrun

The ENDOFRUN segment causes the simulation run to be terminated.

# CHAPTER V

# RESULTS OF THE FOREST MANAGEMENT MODEL

## General

The forest management model was purposely constructed in a very general format. As such, the model has the flexibility to test interactions between several different sets of conditions and decision parameters. Due to the number of experiments required to test all possible alternatives, it was decided to limit model experiments to a representative few which would demonstrate both the usefulness of the model and the nature of the effects of different forest management policies.

## Parameter Combinations Tested

In this study, experiments were limited to differences in demand pattern and speed of response to changes in the condition of the forest resource.

### Demand Pattern

Experiments were made with both constant and ramp demand patterns. Values of demand constant (DEMCON) selected for test were 60,000 and 100,000 cords per year. In addition a ramp increase of 200 cords per year was added to a DEMCON of 60,000 cords per year in some model experiments. The demand patterns tested are summarized in Figure 24.

### Speed of Response

Speed of response reflects the speed with which forest management policy is changed in response to changes in the level of wood available

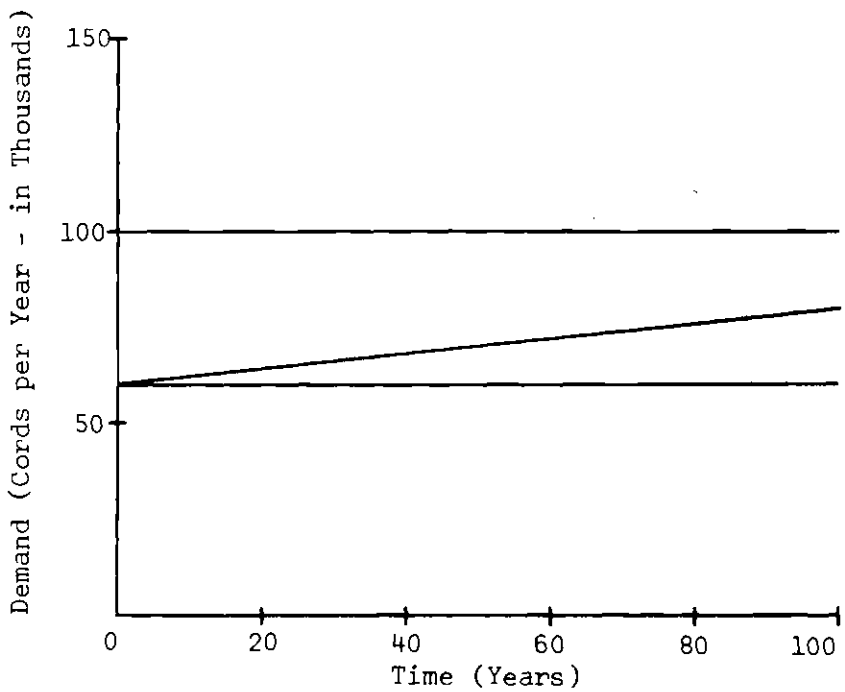


Figure 24. Demand Patterns Tested in the Forest Management Model

for harvesting. The forest management policy itself is manifest in the percentages of acres in the different forest management treatments which are to be clear cut and selective cut and the per cent of cleared land which is to be planted in the following time period.

The speed of response factor is found in the DECISIONCOMPUTE and RATECOMPUTE segments of the program. In each case, Average Demand (AVDEM) is compared with Total Cords on the Stump (TCS) and program logic is switched to one of a set of Decision Labels or Planting Labels based on the outcome of the comparison. Using the values A, B, C, D, and E as response coefficients, the comparison in DECISIONCOMPUTE is made as follows:

```
IF TCS(K) ≥ (A) x (AVDEM[K]) THEN GO TO DL1
ELSE
IF TCS(K) ≥ (B) x (AVDEM[K]) THEN GO TO DL2
ELSE
IF TCS(K) ≥ (C) x (AVDEM[K]) THEN GO TO DL3
ELSE
IF TCS(K) ≥ (D) x (AVDEM[K]) THEN GO TO DL4
ELSE
IF TCS(K) ≥ (E) x (AVDEM[K]) THEN GO TO DL5
ELSE
GO TO DL6
```

TCS[K] - Total Cords on the Stump (Cords)
AVDEM[K] - Average Demand for Pulp (Cords)
DL1,DL2,DL3 - Decision Labels
DL4,DL5,DL6 -

The same comparison is made in the RATECOMPUTE segment of the program with the substitution of Planting Labels for Decision Labels.

If the numerical values of A, B, C, D, and E are taken in decreasing order, it is seen that if there is an abundance of cords on the stump, control is switched to DL1. Likewise, if wood availability is critical, control is switched to DL6. Once program control is passed to one of the Decision Labels or Planting Labels, appropriate forest management parameters are set through the use of the CUTDECISION and PLANTDECISION procedures. The use of six Decision Labels and six Planting Labels allows graduated changes in cutting and planting policy as the condition of the forest resource changes.

Two speeds of response, designated fast and slow, were tested in the model. The response coefficients associated with these two speed of response policies are shown in Table 9.

Table 9. Speed of Response Coefficients

| | Response Coefficients | | | | |
|---|---|---|---|---|---|
| Policy | A | B | C | D | E |
| Slow | 25 | 20 | 15 | 10 | 5 |
| Fast | 21 | 18 | 15 | 12 | 9 |

The combinations of demand pattern and speed of response policy tested in the model are summarized in Table 10 on the following page.

## Results

In this section, some of the most significant results of the forest management model are discussed and examined in terms of graphic plots obtained from tabular output of the model. It must be remembered that the numerical output of the model is heavily dependent on the set of parameters and coefficients used in model formulation. As such, the model results are conditional in nature. Model experiments were not designed to test or evaluate any particular criteria or policy. Real-world application of the model would entail a significant amount of research to determine appropriate parameters, coefficients, and initial conditions prior to actual model experiments.

Table 10. Parameter Combinations Tested in the Forest Management Model

| Run | Response Policy | DEMCON (Cords) | DEMRAM (Cords/Year) |
|---|---|---|---|
| 1 | Slow | 60,000 | 0 |
| 2 | Slow | 60,000 | 200 |
| 3 | Fast | 60,000 | 200 |
| 4 | Slow | 100,000 | 0 |
| 5 | Fast | 100,000 | 0 |

Each experiment with the model yields tabular data for each of the 100 time periods in the simulation run. Significant data values produced include the current demand (DEMAND), the average demand (AVDEM), total cords on the stump (TCS), total acres and cords to be cut during the next time interval, yield in cords per acre (CPA) for the next time interval, the unsatisfied demand for the next time interval, and a complete listing of the values (number of acres) of each of the 420 "blocks" of land in the model. Inclusion of all tabular results produced is not feasible, however a sample of the numerical data obtained for one year of one simulation run is shown in Appendix F.

Examination of the graphical plots of significant variables reveals that plots for two of the five simulation runs are not complete through 100 time periods. This discrepancy was caused by a divide-by-zero error which occurred under certain circumstances in the CUTDECISION procedure. Although this procedure was analyzed in detail in an attempt to isolate and correct the error, the cause of the error was not found. It should be noted that occurrence of the divide-by-zero error does not invalidate results obtained for time periods prior to the occurrence of the error.

Plots of total cords on the stump (TCS) vs. TIME for the five model experiments are shown in Figures 25 through 29. In each figure the time scale goes from zero to 100 (Years) and TCS assumes values between zero and 1,700,000 cords.

In run No. 1, demand was held constant at 60,000 cords per year and the management response policy was slow. In Figure 25, TCS is seen to increase to a maximum after 21 years of harvesting and then falls off continuously to a minimum at YEAR=46 (divide-by-zero error). This peaking characteristic is indicative of the fact that after several years of harvesting, the number of acres of mature timber decreased, resulting in a reduction in the number of cords on the stump. The slow management response policy resulted in gradual changes in the value of TCS. The divide-by-zero error precluded the analysis of long-term trends in this run.

In run No. 2, the response policy was again slow; however, a ramp demand increase of 200 cords per year was added to the initial

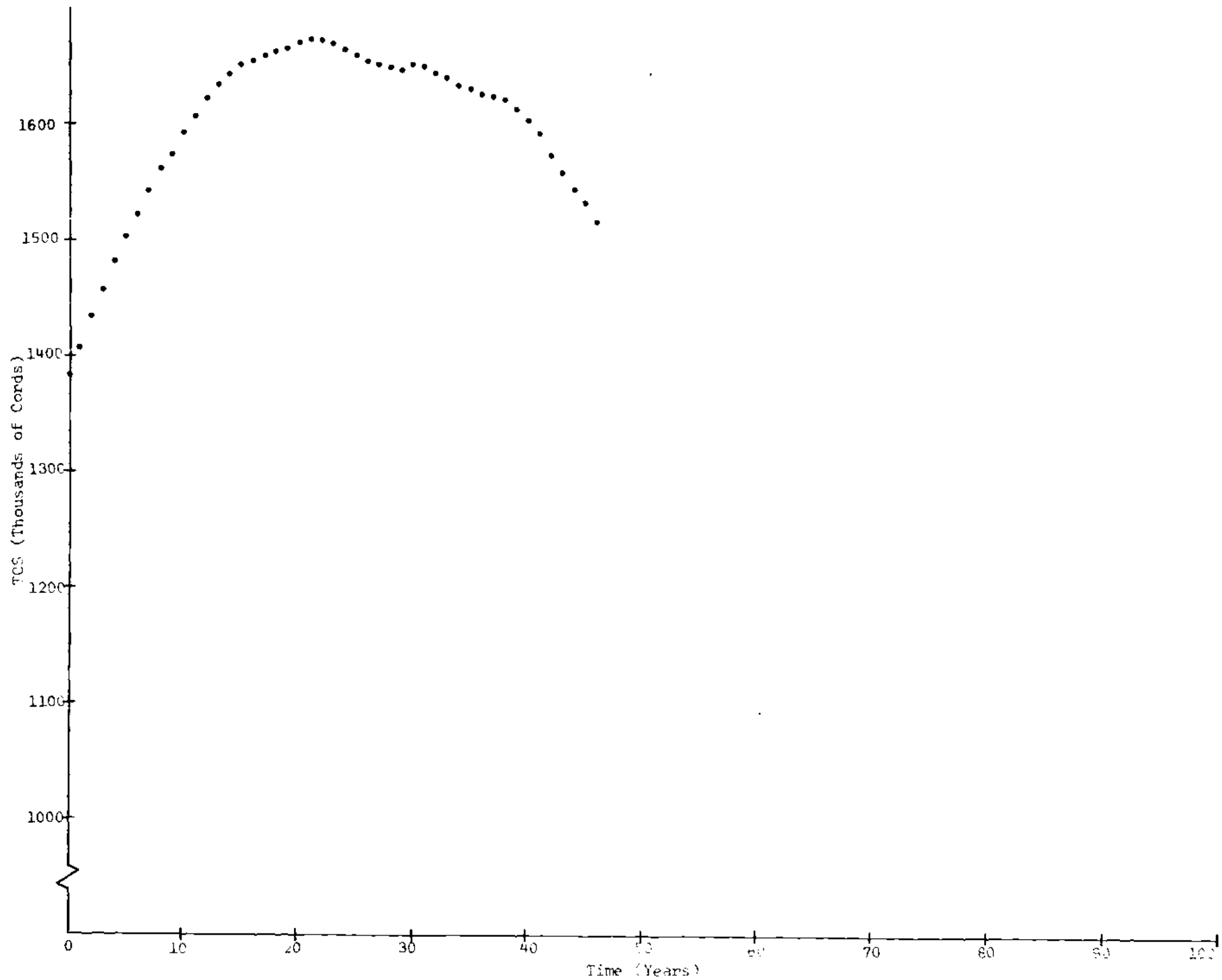


Figure 25. Plot of TCS vs. TIME for Run No. 1 of the Forest Management Model

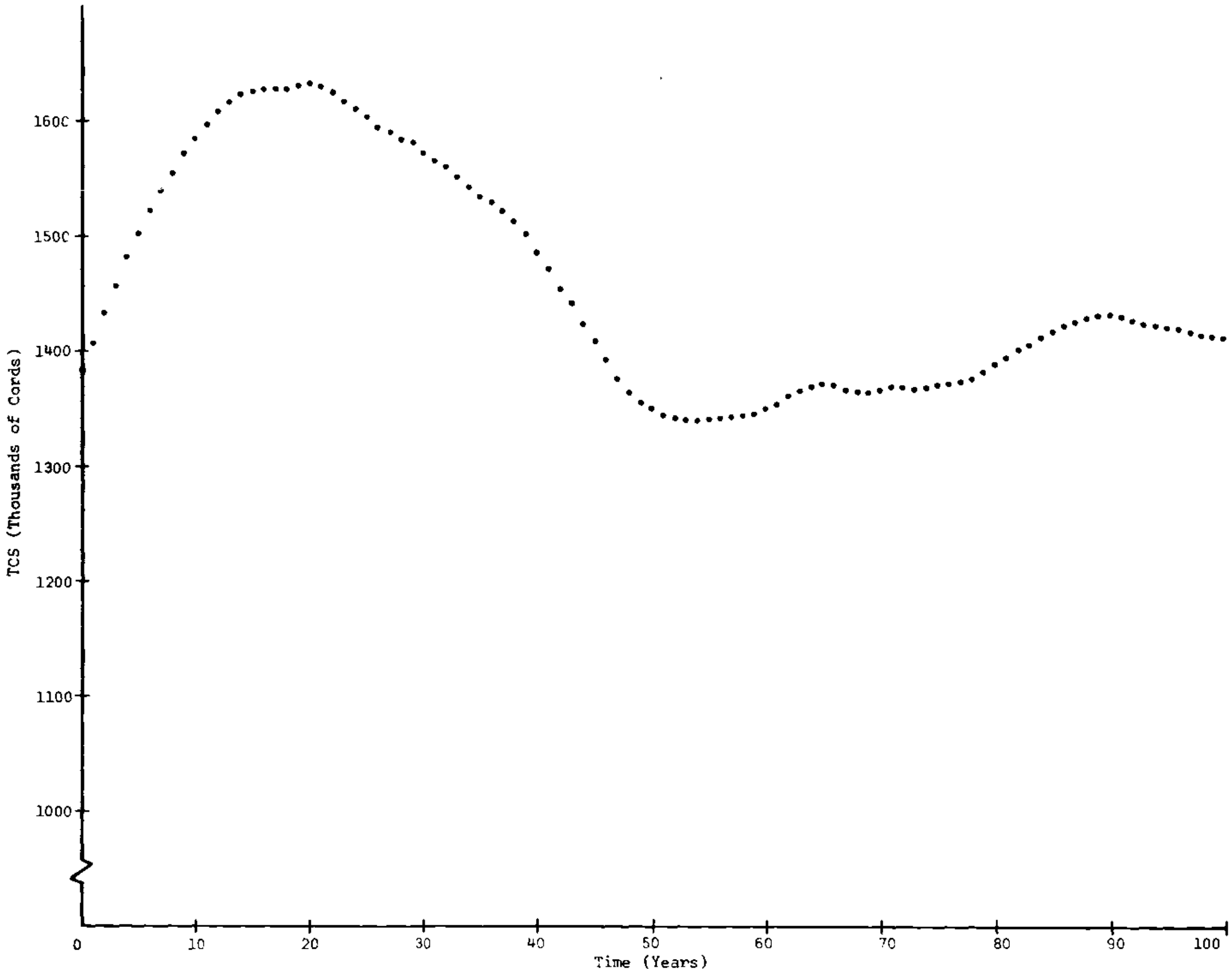


Figure 26. Plot of TCS vs. TIME for Run No. 2 of the Forest Management Model

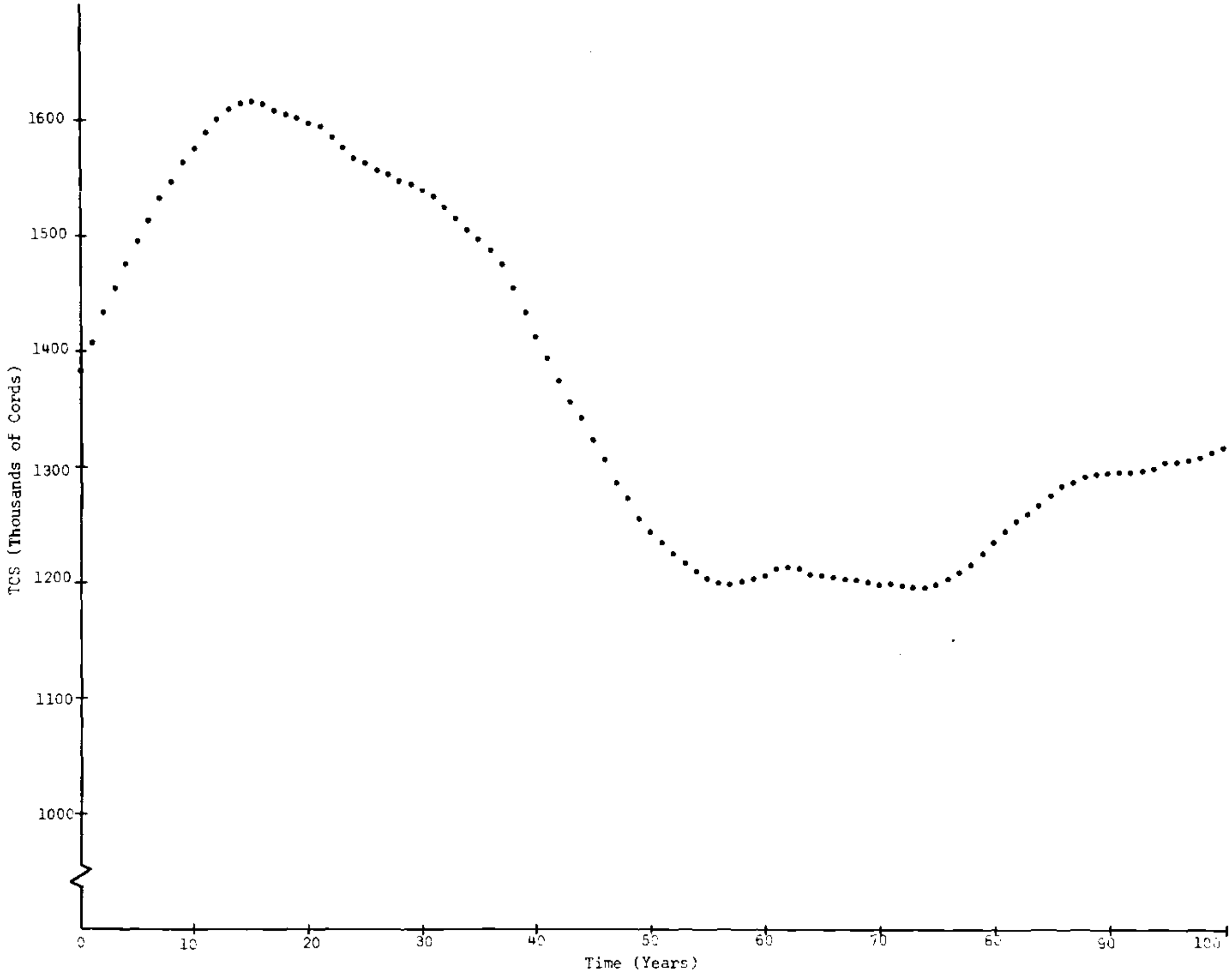


Figure 27. Plot of TCS vs. TIME for Run No. 3 of the Forest Management Model

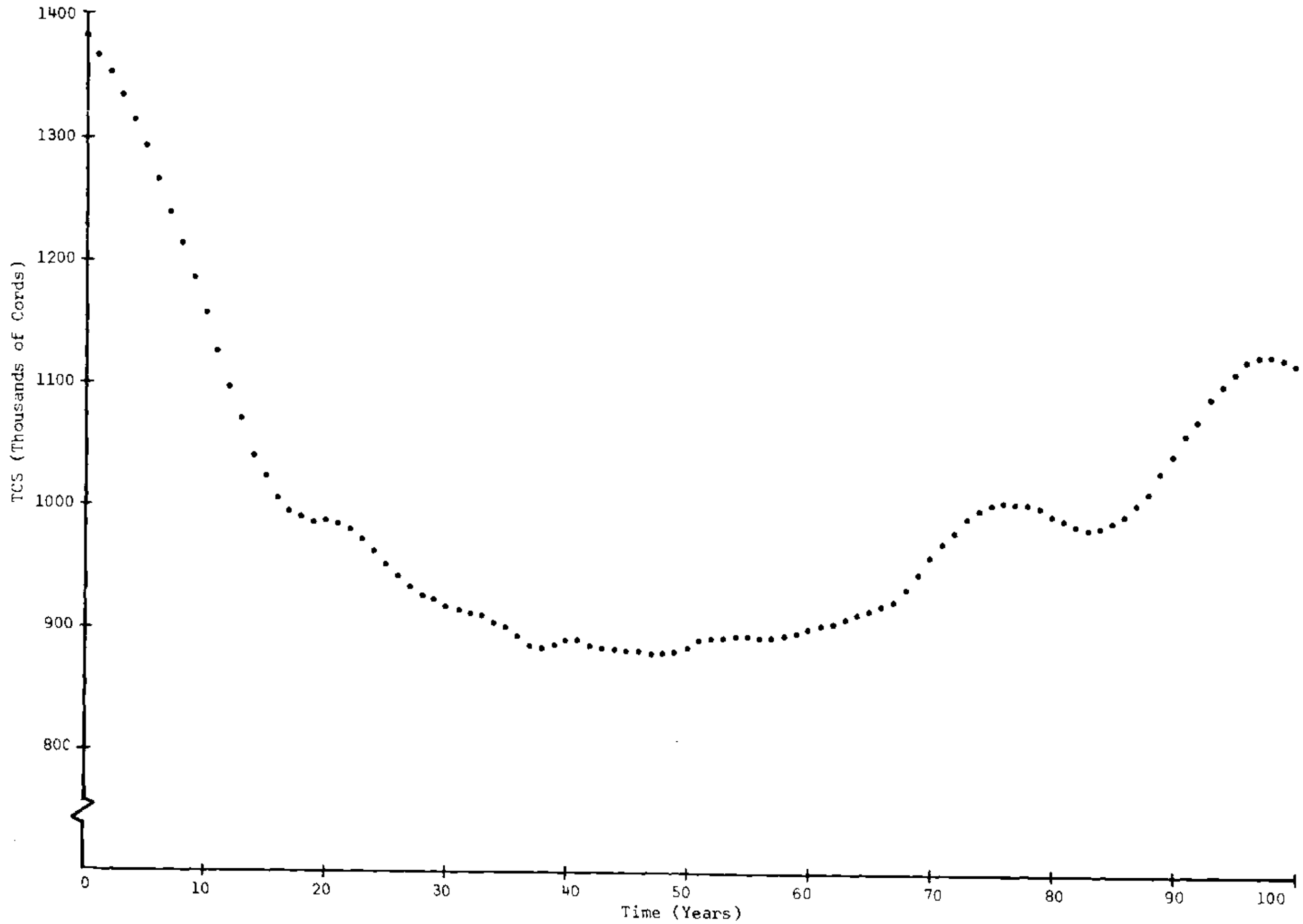


Figure 28. Plot of TCS vs. TIME for Run No. 4 of the Forest Management Model

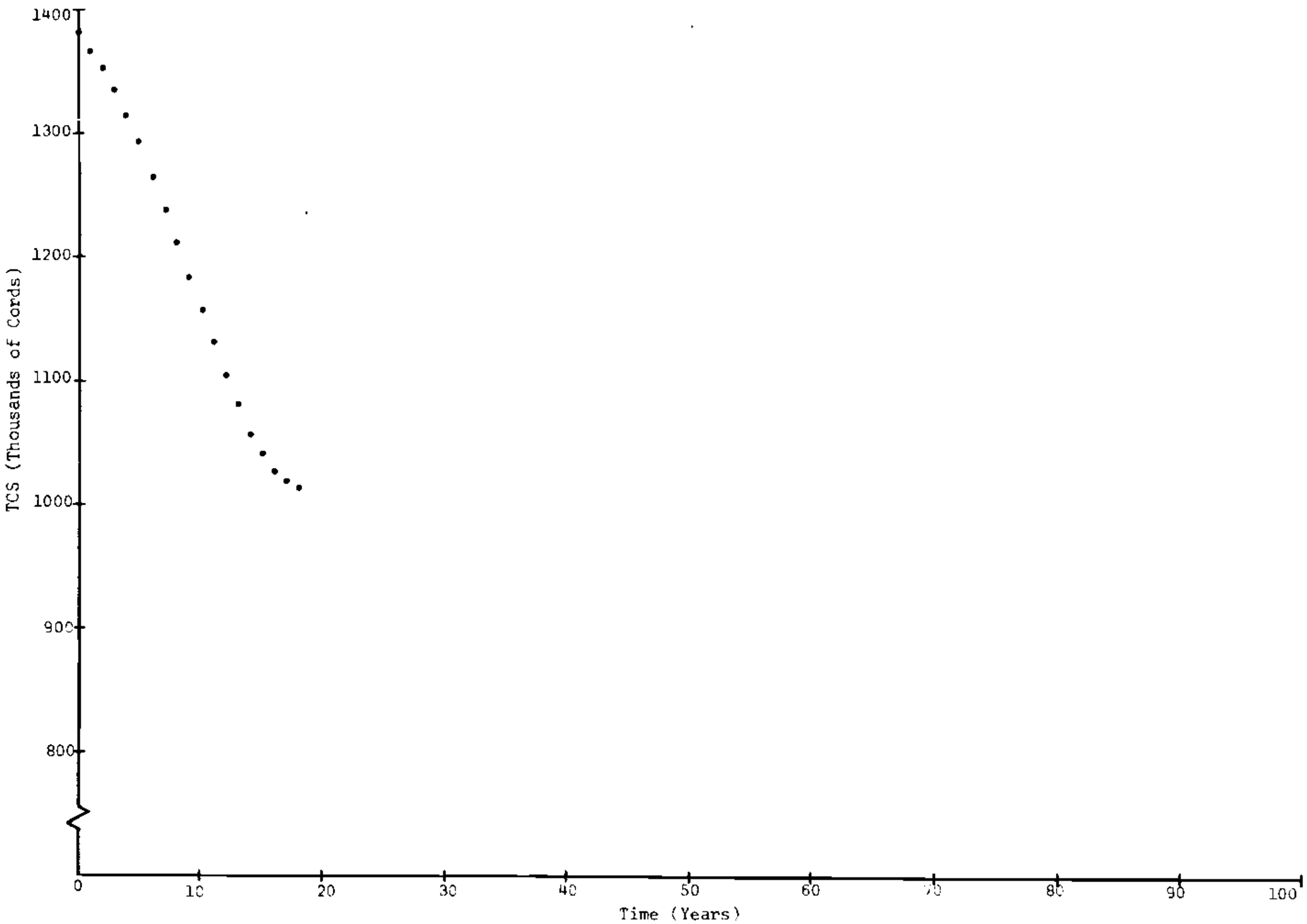


Figure 29. Plot of TCS vs. TIME for Run No. 5 of the Forest Management Model

demand of 60,000 cords per year. The plot of TCS vs. TIME (Figure 26) shows the same peaking characteristic as in run No. 1; however, the peak occurs earlier (YEAR=20) and is of a smaller magnitude than in run No. 1. This is interpreted as a result of the increasing magnitude of DEMAND coupled with the slow response policy. The long term behavior of TCS shows a trend towards stabilization around a value of TCS= 1,400,000. This stability indicates the ability of the management response policy to adjust TCS to a changing demand over a long period of time.

In run No. 3, the same demand pattern was used as in run No. 2; however, a fast management response policy was implemented. Results of run No. 3 (Figure 27) are quite similar to the results obtained with a slow response policy. However, the maximum value of TCS occurred earlier (YEAR=15) and is of a smaller magnitude than in run No. 2. In the long run, the fast response policy resulted in more rapid changes in TCS; however, the same stabilizing tendency of TCS is evident.

In run No. 4, demand was held constant at 100,000 cords per year and the management response policy was slow. Figure 28 immediately shows the effect of the increase in demand. TCS decreases continually during the first 38 years of the simulation run and does not make significant increases until after YEAR=60. The long-term trend of TCS vs. TIME indicates wide fluctuations in TCS; however, it is noted that the model does tend towards regulation of the forest resource.

In run No. 5, demand was again held constant at 100,000 cords per year; however, a fast management policy was tested. Although results for this run (Figure 29) were hindered by a divide-by-zero error at

YEAR=18, the plot of TCS vs. TIME for the first 18 years is quite similar to the results of run No. 4 (slow response policy). It is noted, however, that the plot of TCS shows signs of "flattening out" somewhat after YEAR=10 indicating the responsive effect of a faster management response policy during a period of time when the quantity of available resources is declining rapidly.

In general, the plot of TCS vs. TIME indicates the long-term interactions between demand and management response policy. Such a plot can be used to evaluate the long-term ability of the forest resource to sustain a given demand pattern under a particular management policy.

Plots of cords per acre (CPA) vs. TIME for the five model experiments are shown in Figures 30 through 34. The value of CPA plotted always refers to the next time interval. That is, the value of CPA at TIME=5 represents the cords harvested per acre during the period from TIME=5 to TIME=6. It is assumed of course that all harvesting is done according to the policies and rates established at TIME=5.

The value of CPA is a reflection of the productivity of the land harvested in a particular year. Stated differently, the value of CPA depends on which blocks in the cutting sequence have merchantable wood available for harvesting at a particular point in time. For a given demand, a high value of CPA indicates that the demand is satisfied by harvesting a relatively small number of acres of land with a high yield. Conversely, a low value of CPA indicates that a large number of acres of lesser productivity are required to satisfy the demand.

Examination of Figures 30 through 34 indicates that the plots of CPA vs. TIME are very similar. Variations in CPA appear to be the result

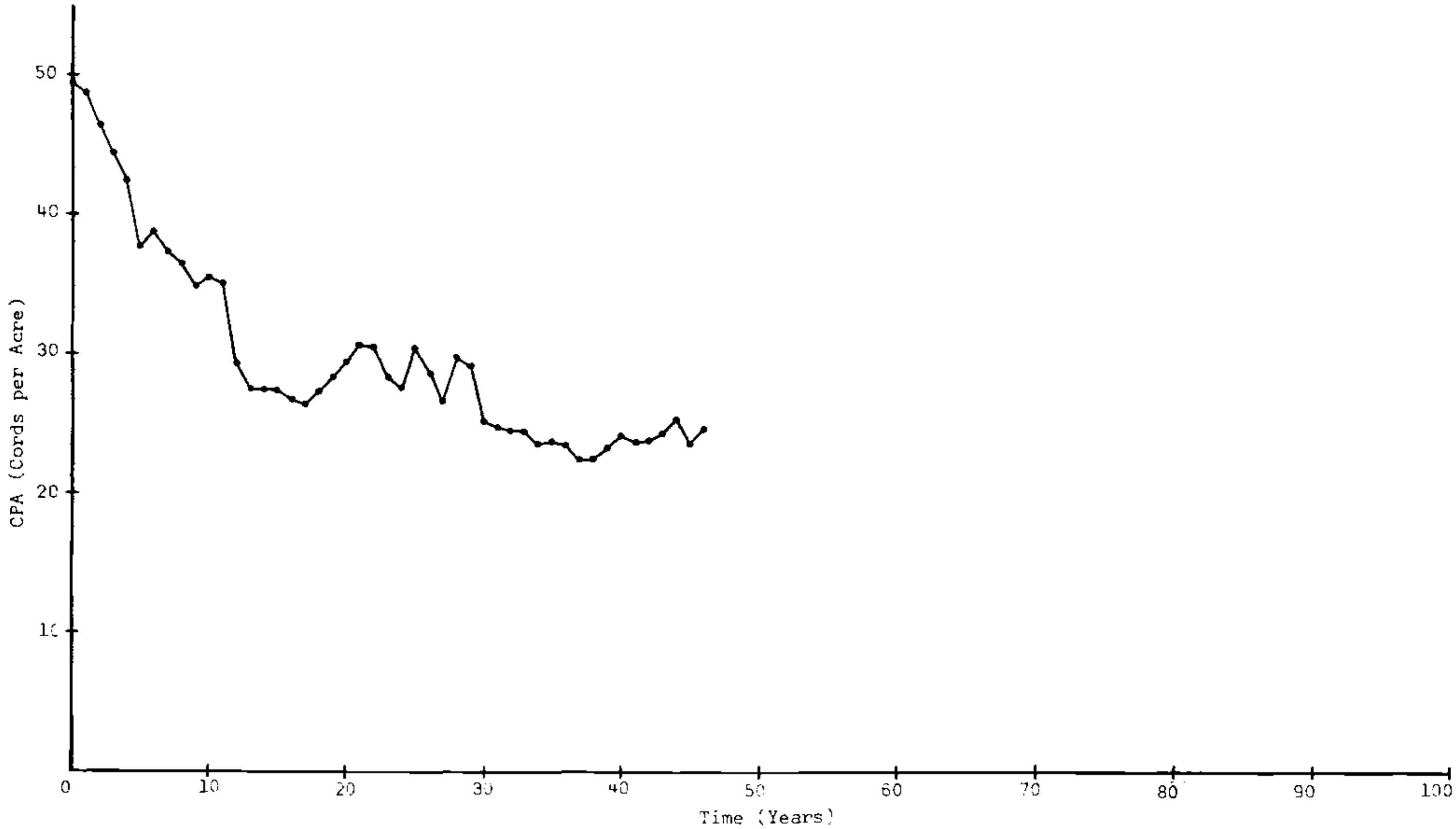


Figure 30. Plot of CPA vs. TIME for Run No. 1 of the Forest Management Model

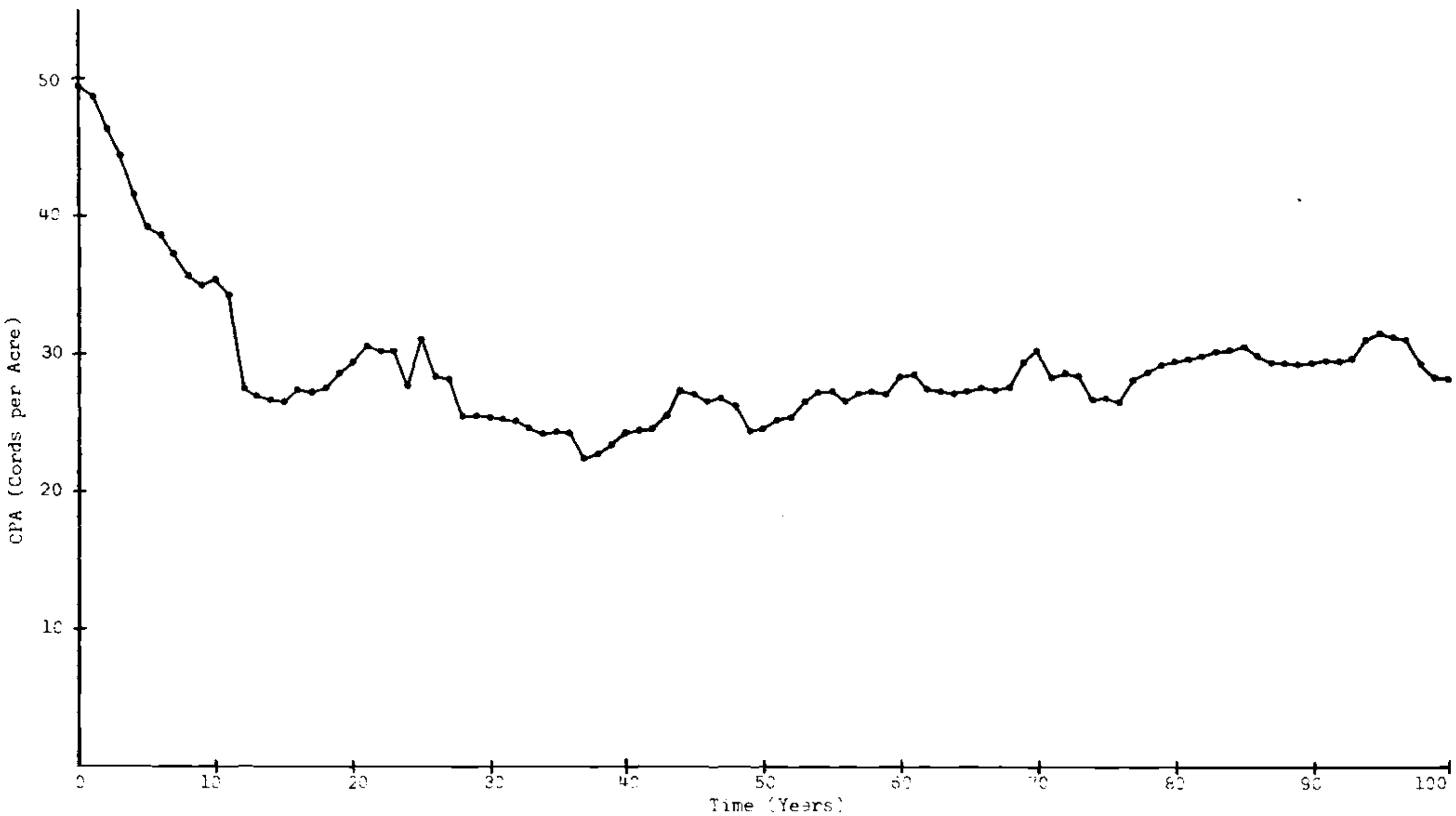


Figure 31. Plot of CPA vs. TIME for Run No. 2 of the Forest Management Model

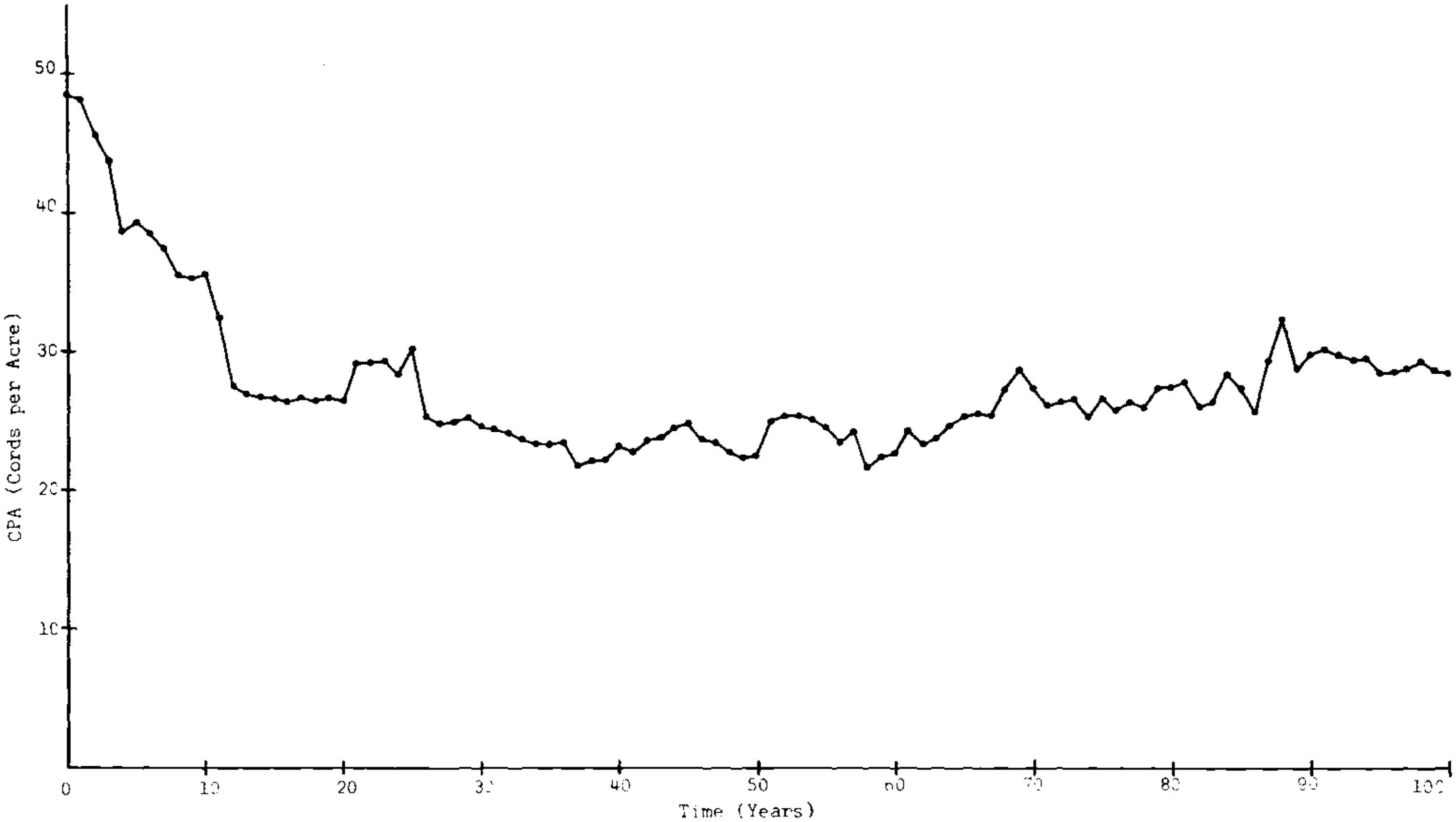


Figure 32. Plot of CPA vs. TIME for Run No. 3 of the Forest Management Model

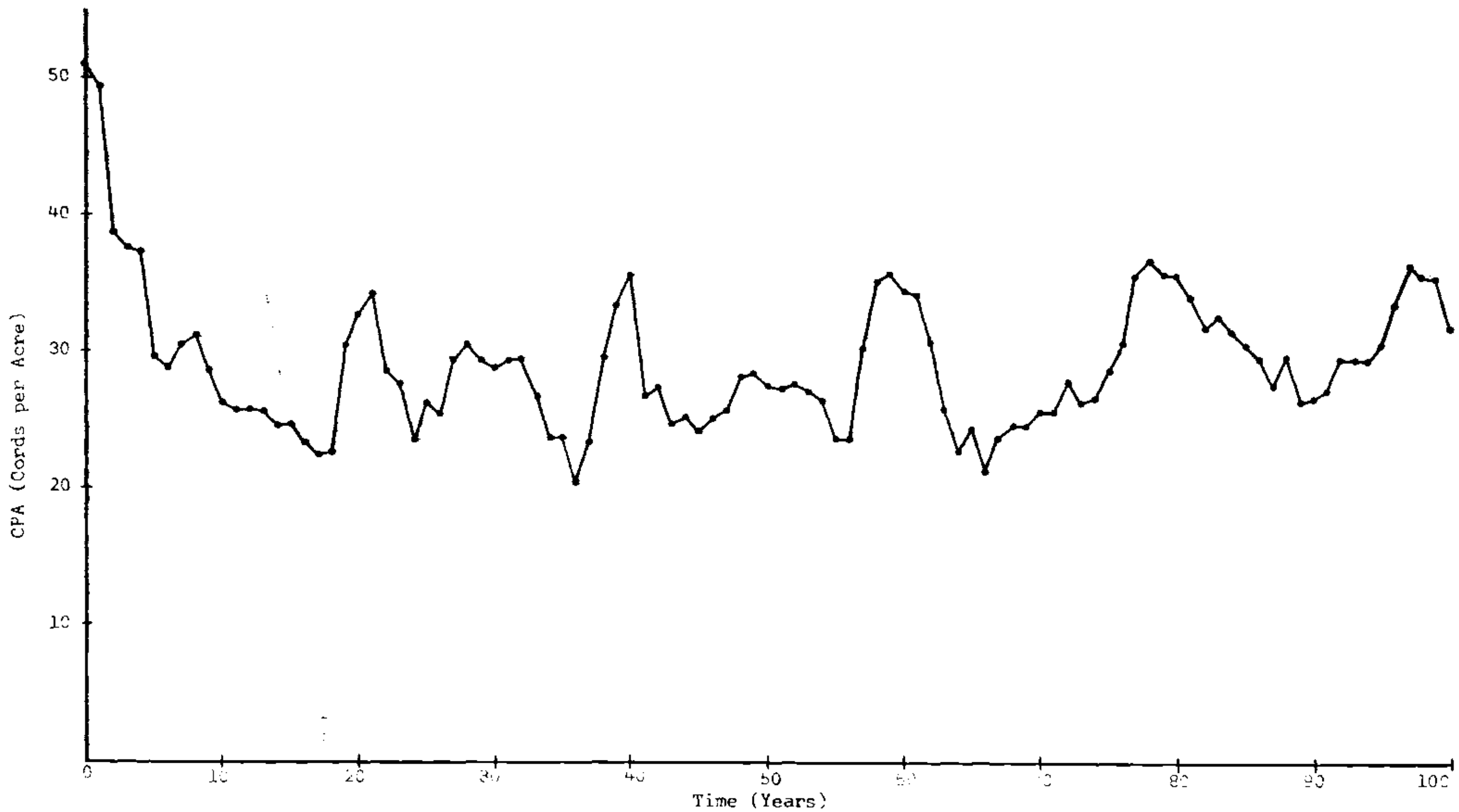


Figure 33. Plot of CPA vs. TIME for Run No. 4 of the Forest Management Model

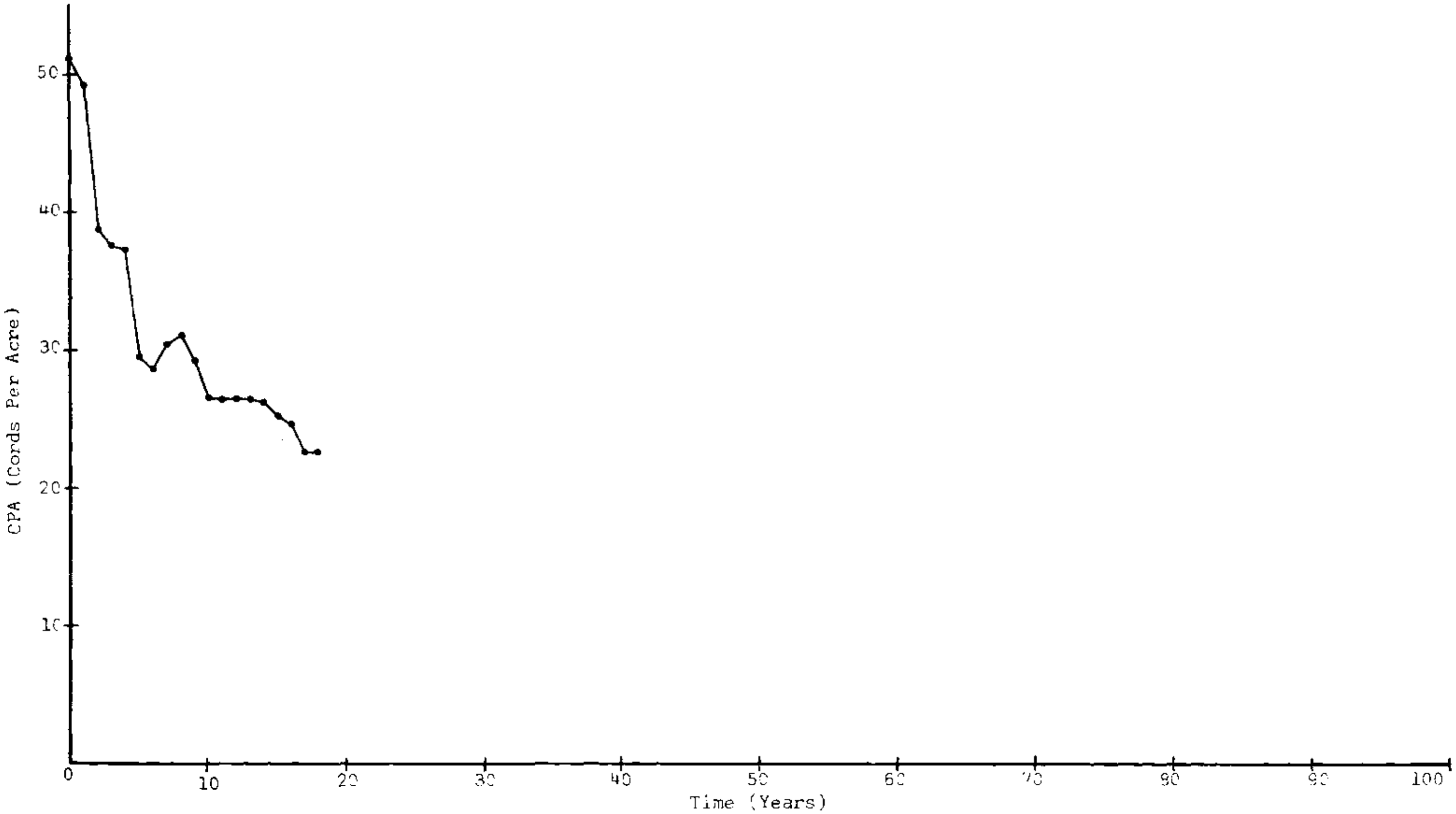


Figure 34. Plot of CPA vs. TIME for Run No. 5 of the Forest Management Model

of short-term random fluctuations rather than long-term trends. In all cases, the value of CPA appears to vary around an average of approximately 27 cords per acre. This figure is of course a function of the yield coefficients built into the model. The shifts in CPA are interpreted as a function of the changes in the nature of the forest resource over time. That is, the availability of merchantable timber in any given year. It must be remembered that the predetermined cutting sequence determines the CPA of successive blocks of land in the cutting sequence. Thus in the early years of the simulation mature, highly productive stands are available for harvesting. Also, each year acres are "flowing" into these highly productive blocks. In the long run, the model seeks a steady-state condition where the blocks with timber available for harvesting each year are a function of the interaction between demand and the speed of management response.

Figures 30 and 31 are almost identical over the ranges shown. Both of these runs (Nos. 1 and 2) involve a slow response policy. Run No. 1 was based on a constant demand of 60,000 cords per year, whereas run No. 2 involved an annual increase of 200 cords. For these two conditions, the general level of demand was such that approximately the same balance between demand and response policy was established. In the extremely long run, the gradual increase in demand in run No. 2 would be expected to deplete the forest resource, resulting in gradually decreasing values of CPA.

Run No. 3 (Figure 32) was identical with run No. 2, except for the change to a fast response policy. Much like the plots of TCS vs.

TIME for these two runs, the plots of CPA vs. TIME are very similar throughout the simulation runs.

Runs Nos. 4 and 5 (Figures 33 and 34) were both characterized by a constant demand of 100,000 cords per year. Run No. 4 involved a slow response policy whereas run No. 5 incorporated a fast policy. The plots of CPA vs. TIME, for the ranges available for comparison, again show great similarity. It is noted, however, that the higher level of demand resulted in wider fluctuations in CPA (see Figures 30 and 33 for a comparison of constant demands of 60,000 and 100,000 cords per year, each with a slow response policy). This is interpreted to be a result of the increased "strain" imposed on the forest resource under the higher demand level. (See Figures 25 and 28 for a graphic display of the differences in TCS for these two model experiments.) It is noted, however, that even under a demand of 100,000 cords per year, the value of CPA still averaged approximately 27 over the long run.

In addition to the trend or "status" information provided by plots of TCS and CPA vs. TIME, the forest management model is capable of producing operational data of use in managing a large-scale forest resource. Given an anticipated demand pattern and assuming a managerial response policy together with its attendant numerical parameters, the model can be programmed to yield a table of cutting rates for every block of land for the length of the simulation run. Under the set of assumptions inherent in the model, these values can be implemented in the operational management of the forest resource.

In summarizing the results of the forest management model, the conditional nature of the numerical results must again be stressed.

In this study, emphasis has been placed on the development of measures of trends or relationships between forest management decisions and the long-term capability of the forest resource to meet a continuing demand for pulp. The simulation technique is one of experimentation with a small percentage of the infinite combinations of factors that may be present in the real-world system. As such, no general "laws" of optimal forest management policy can be deduced from this study.

# CHAPTER VI

# CONCLUSIONS AND RECOMMENDATIONS

## Conclusions

The main objective of this study, as stated in Chapter I, was the development of a technique whereby the individual pulp-producing company could evaluate the level of forest management required to support a continuing demand for pulp from a limited company controlled forest resource. This objective was reached through the construction of two interrelated digital simulation models. The first, a forest investment model, is intended for use in evaluating the profitability of different forest management treatments on different types of land. The second, a general forest management model, is intended for use in a simulation approach to the management of a heterogenous forest resource. The use of the two models provides a technique that incorporates the dual objectives of profitable investment and satisfaction of a changeable annual demand into a single management tool.

The models as developed clearly display the characteristics of utility and flexibility. The models are general in nature and can be utilized in widely-varying circumstances. Sufficient flexibility is available to allow consideration of wide varieties of managerial policies, types of land, and demand patterns. The models can operate on different sets of parameter values and input conditions with minimal inconvenience to the programmer. In addition, model formulation is logical and can be interpreted and understood in terms of real-world understanding.

In evaluating results and stating conclusions, it must be remembered that this study was aimed at the development of a general technique. No attempt was made to determine an optimal forest management policy. Such an effort would require extensive experimentation with different parameters and would still yield only conditional results. As a result of this study, however, several conclusions can be stated with regard to the nature of forest management.

1. Discounted cash flow or rate-of-return analysis based on the individual acre or "block" of land can be effectively applied to the evaluation of forest management alternatives. The forest investment model, as developed, is a simplification of the broad-scale model needed to evaluate complex alternatives. The rate-of-return approach is straightforward and efficient and can be used to evaluate many combinations of policies and parameters.

2. Within the current range of costs and revenues associated with pulpwood harvesting, the primary factor in profitability is the growing capability of the land (site index). In particular, the greater the site index, the greater the potential rate of return.

3. In any large-scale harvesting operation, investment in plantation management will increase the rate of return on invested capital regardless of the growing capability of the land.

4. The simulation approach to forest management is capable of yielding significant benefits to woodlands managers. In that the simulation approach allows the incorporation of two or more objectives in

the basic analytic structure, it provides the mechanism for bridging the gap between the traditional forest regulation model and the financial maturity approach.

5. The general demand level (as opposed to demand pattern) imposed on a given forest resource is the largest single determinant of the capability of the resource to satisfy a long-term demand for wood.

6. The stability of cords harvested per acre from a given forest resource is affected to some degree by the long-term demand; however, the level and range of cords per acre is primarily a function of the capabilities of the growing stock.

7. Prudent and effective forest management will result in significantly better forest output (as measured by cords harvested per acre) than is currently being realized from Southern company-owned forest resources.

## Recommendations

Based on the experience gained while carrying out this study, numerous lines of potential future investigation are evident. Both in-depth studies of particular aspects of forest management and further development of the overall technique proposed in this study are recommended.

Of prime concern in the development of the forest management model proposed in this study is the elimination of the divide-by-zero error which occurred under certain circumstances in the CUTDECISION procedure. Although this error does not invalidate results of the model, it hinders implementation and testing of the model under differing sets of input conditions.

A significant improvement could be realized by streamlining the forest management model to effect greater computational efficiency and hence a reduction in computer time. As developed, the model is not economical in terms of the computer time required for a simulation run.

The forest investment model could be further developed to allow more flexibility for testing and evaluating such things as thinning operations and multi-product forest management. In this respect, research is needed in the areas of optimal thinning intensity and cycles and the systems and financial aspects of multi-product logging.

The forest management model could be expanded by the inclusion of costs and revenues in the model. By incorporating financial considerations, forest management could be evaluated from the standpoint of cost-benefit analysis.

Much research is needed on genetic improvements in the tree itself. Such improvements could, over a period of time, significantly change the cutting sequence as determined by the forest investment model. As such, it would be advantageous to couple the two models together. The forest investment model could be incorporated in the forest management model as a loop procedure to be executed every year in the simulation run. As such, the harvesting sequence could be altered as changes in forest growth behavior effect the rate-of-return picture for the individual "blocks" of land. The FORTRAN language is suggested for this purpose.

Lastly, as a test of the value of the approach presented here, experiments should be conducted using data and parameters representative of a particular real-world woodlands operation. As such, model results could be compared with real-world results using current forest management procedures.

# APPENDIX A

# THE FOREST INVESTMENT MODEL

```
RDR.......RATE OF RETURN ON INITIAL INVESTMENT   (PERCENT)
RDRAUX....AUXILTARY NEEDED TO COMPUTE RATE OF RETURN FOR
             CURRENT YEAR   (DIMENSIONLESS)
RDRFAC....RATE OF RETURN FACTOR FOR CURRENT YEAR   (PERCENT)
SPPC......SITE PREPARATION AND PLANTING COST   (DOLLARS/ACRE)
STMPC.....CURRENT STUMPAGE PRICE   (DOLLARS/CORD)
STMPI.....INITIAL STUMPAGE PRICE   (DOLLARS/CORD)
TAXRC.....CURRENT TAX RATE   (DOLLARS/ACRE)
TAXRI.....INITIAL TAX RATE   (DOLLARS/ACRE)
TIVMAN....TOTAL INITIAL VALUE OF LAND MANAGEMENT COSTS PAID
             THROUGH END OF CURRENT YEAR   (DOLLARS/ACRE)
TIVTAX....TOTAL INITIAL VALUE OF TAXES PAID THROUGH END OF
             CURRENT YEAR   (DOLLARS/ACRE)
UNITY.....CONSTANT OF ONE   (DIMENSIONLESS)
WOODC.....CURRENT WOOD VALUE   (DOLLARS/ACRE)
YEAR......CURRENT YEAR
YEAR1.....CURRENT YEAR PLUS ONE
YIELD.....YIELD OF LAND   (CORDS/ACRE)
YINRA.....YEARLY INCREMENT RATE   (1)
YLD.......YIELD TABLE   (CORDS/ACRE)
YRAUX1....COMPUTATIONAL AUXILIARY USED TO AVOID DIVISION BY
             ZERO WHEN YEAR EQUALS ZERO
YRAUX2....COMPUTATIONAL AUXILIARY USFD TO AVOID DIVISION BY
             ZERO WHEN YEAR EQUALS ZERO
YRFAC.....YEAR FACTOR = ONE DIVIDED BY THE CURRENT VALUE OF
             YEARS
```

THE MODEL

SYSTEMS EQUATIONS

```
1L     YEAR.K=YEAR.J+(DT)(YINRA+0)
59A    YIELD.K=TABLE(YLD,YEAR.K,0,50,1)
7A     INFRA.K=UNITY+INFLC
29A    INAUX.K=(YEAR.K)LOGN(INFRA.K)
28A    INFAC.K=(UNITY)EXP(INAUX.K)
12A    STMPC.K=(INFAC.K)(STMPI)
12A    WOODC.K=(YIELD.K)(STMPC.K)
12A    LANDC.K=(INFAC.K)(LANDI)
7A     ASSVC.K=LANDC.K+WOODC.K
12A    MANGC.K=(INFAC.K)(MANGI)
7A     YEAR1.K=YEAR.K+UNITY
29A    INAUX1.K=(YEAR1.K)LOGN(INFRA.K)
28A    INFAC1.K=(UNITY)EXP(INAUX1.K)
12A    TAXRC.K=(INFAC1.K)(TAXRI)
7A     CINVF.K=UNITY+INTRC
29A    INAUXC.K=(YEAR1.K)LOGN(CINVF.K)
28A    INTFAC.K=(UNITY)EXP(INAUXC.K)
20A    DISFAC.K=UNITY/INTFAC.K
12R    DISTAX.KL=(DISFAC.K)(TAXRC.K)
1L     TIVTAX.K=TIVTAX.J+(DT)(DISTAX.JK+0)
6R     DFDELR.KL=DISFAC.K
6A     DFDELA.K=DFDELR.JK
12R    DISMAN.KL=(DFDELA.K)(MANGC.K)
1L     TIVMAN.K=TIVMAN.J+(DT)(DISMAN.JK+0)
9A     IVTIV.K=LANDI+SPPC+TIVTAX.K+TIVMAN.K
7A     PROF.K=ASSVC.K-IVTIV.K
20A    RATEO.K=ASSVC.K/IVTIV.K
```

```
?USER= 8107033, BIN 0259
?COMPILE BIN0259/GAV     DYNAMO         .23S800012   *0259 VALENTE G A
?FILE W = GAVOUT FORM BACK UP TAPE .
?PROCESS=0015;IO=0015.
?COMMON= 002591;FILE DYNAMO= D002591 ;DATA D002591.

            RUN   P1R1

                          FOREST INVESTMENT MODEL

                      RATE OF RETURN CALCULATIONS

                      LAND DESCRIPTION
                      SITE INDEX 30
                      MANAGEMENT POLICY: NATURAL REGENERATION

                          ALPHABETICAL LIST OF SYMBOLS

                      ASSVC.....CURRENT VALUE OF ASSETS   (DOLLARS/ACRE)
                      CINVF.....CAPITAL INVESTMENT FACTOR   (PERCENT)
                      DFDELA....DISCOUNT FACTOR DELAY AUXILIARY - NEEDED TO DELAY
                                DISCOUNT FACTOR ONE TIME PERIOD
                                (DIMENSIONLESS)
                      DFDELR....DISCOUNT FACTOR DELAY RATE - NEEDED TO DELAY
                                DISCOUNT FACTOR ONE TIME PERIOD
                                (DIMENSIONLESS)
                      DISFAC....DISCOUNT FACTOR FOR CURRENT CAPITAL
                                (DIMENSIONLESS)
                      DISMAN....DISCOUNTED VALUE OF NEXT YEARS LAND MANAGEMENT
                                COST   (DOLLARS/ACRE)
                      DISTAX....DISCOUNTED VALUE OF NEXT YEARS TAXES
                                (DOLLARS/ACRE)
                      INAUX.....AUXILIARY NEEDED TO COMPUTE INFLATION FACTOR FOR
                                CURRENT YEAR   (DIMENSIONLESS)
                      INAUXC....AUXILIARY NEEDED TO COMPUTE INTEREST FACTOR FOR
                                IDLE CAPITAL   (DIMENSIONLESS)
                      INAUX1....AUXILIARY NEEDED TO COMPUTE INFLATION FACTOR FOR
                                CURRENT YEAR PLUS ONE   (DIMENSIONLESS)
                      INFAC.....INFLATION FACTOR FOR CURRENT YEAR   (DIMENSIONLESS)
                      INFAC1....INFLATION FACTOR FOR CURRENT YEAR PLUS ONE
                                (DIMENSIONLESS)
                      INFLC.....INFLATION CONSTANT   (PERCENT)
                      INFRA.....INFLATION RATE   (PERCENT)
                      INTFAC....INTEREST FACTOR FOR CURRENT YEAR   (DIMENSIONLESS)
                      INTRC.....INTEREST RATE FOR IDLE CAPITAL   (PERCENT)
                      IVTIV.....INITIAL VALUE OF TOTAL INVESTMENT   (DOLLARS/ACRE)
                      LANDC.....CURRENT LAND VALUE   (DOLLARS/ACRE)
                      LANDI.....INITIAL LAND COST   (DOLLARS/ACRE
                      MANGC.....CURRENT LAND MANAGEMENT COST   (DOLLARS/ACRE)
                      MANGI.....INITIAL LAND MANAGEMENT COST   (DOLLARS/ACRE)
                      PROF......TOTAL PROFIT AT END OF CURRENT YEAR
                                (DOLLARS/ACRE)
                      PROFYR....PROFIT PER YEAR   (DOLLARS/ACRE)
                      RATED.....RATIO OF CURRENT VALUE OF ASSETS TO INITIAL VALUE
                                OF TOTAL INVESTMENT   (DIMENSIONLESS)
```

```
51A     YRAUX1.K=CLIP(0,1,YEAR.K,1)
7A      YRAUX2.K=YEAR.K+YRAUX1.K
20A     YRFAC.K=UNITY/YRAUX2.K
12A     PROFYR.K=(YRFAC.K)(PROF.K)
29A     RORAUX.K=(YRFAC.K)LOGN(RATEO.K)
28A     RORFAC.K=(UNITY)EXP(RORAUX.K)
7A      ROR.K=RORFAC.K-UNITY

                    INITIAL CONDITIONS

6N      DFDELA=1.00
6N      TIVMAN=0
6N      TIVTAX=0
6N      YEAR=0

                    CONSTANTS

C       INFLC=.035
C       INTRC=.07
C       LANDI=50
C       MANGI=1.00
C       SPPC=30
C       STMPI=7.50
C       TAXRI=1.00
C       UNITY=1.0
C       YINRA=1
C       YLD*=0.0/0.0/0.0/0.0/0.0/0.0/0.0/0.0/0.0/0.0/0.0/0.0/0.0/0.9/1.5/2
X1      .1/2.6/3.2/3.7/4.2/4.8/5.3/6.0/6.6/7.3/7.8/8.5/9.0/9.6/10.1/10.8/1
X2      1.4/12.1/12.6/13.2/13.6/14.0/14.6/15.1/15.7/16.2/16.6/17.1/17.5/18
X3      .0/18.5/18.9/19.4/19.8/20.2/20.7

PRINT 1)ROR/2)PROF,PROFYR/3)STMPC,WOODC/4)LANDC/5)MANGC/6)TAXRC/7)ASSVC/
X1      8)TIVMAN/9)TIVTAX/10)IVTIV/11)INFAC,INFAC1/12)INTFAC,DISFAC/13)DFD
X2      ELA
PLOT    ROR=R(-0.05,0.15)/PROF=P(0,5000)/PROFYR=Y(0,100)
SPEC    DT=1/LENGTH=50/PRTPER=1/PLTPER=1
```

```
INPUT PHASE CONCLUDED AT   19: 1  4
                                                  ESTIMATED PRT REQUIREMENT = 343

GENERATION PHASE BEGAN AT 19: 1  6
RUN  PHASE  GENERATED AT   19: 1 16
PRINT PHASE GENERATED AT   19: 1 18
PLOT PHASES GENERATED AT   19: 1 20

ELAPSED COMPILATION TIME       0 26
```

# APPENDIX B

## SAMPLE TABULAR OUTPUT OF THE FOREST INVESTMENT MODEL

| TIME | ROR | PROF<br>PROFYR | STMPC<br>WOODC | LANDC | MANGC | TAXRC | ASSVC | TIVMAN | TIVTAX | TVTIV | INFAC<br>INFAC1 | INTFAC<br>DISFAC | DFDELA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E+00 | E+00 | E+00<br>E+00 | E+00<br>E+00 | E+00 | E+00 | E+00 | E+00 | E+00 | E+00 | E+00 | E+00<br>E+00 | E+00<br>E+00 | E+00 |
| 0.000 | -.37500 | -30.0<br>-30.000 | 7.500<br>0.00 | 50.00 | 1.0000 | 1.0350 | 50.0 | 0.000 | 0.000 | 80.00 | 1.0000<br>1.0350 | 1.070<br>0.93458 | 1.0000 |
| 1.000 | -.36865 | -30.2<br>-30.217 | 7.763<br>0.00 | 51.75 | 1.0350 | 1.0712 | 51.8 | 1.000 | 0.967 | 81.97 | 1.0350<br>1.0712 | 1.145<br>0.87344 | 0.9346 |
| 2.000 | -.20086 | -30.3<br>-15.154 | 8.034<br>0.00 | 53.56 | 1.0712 | 1.1087 | 53.6 | 1.967 | 1.903 | 83.87 | 1.0712<br>1.1087 | 1.225<br>0.81630 | 0.8734 |
| 3.000 | -.13519 | -30.3<br>-10.092 | 8.315<br>0.00 | 55.44 | 1.1087 | 1.1475 | 55.4 | 2.903 | 2.809 | 85.71 | 1.1087<br>1.1475 | 1.311<br>0.76290 | 0.8163 |
| 4.000 | -.10011 | -30.1<br>-7.529 | 8.606<br>0.00 | 57.38 | 1.1475 | 1.1877 | 57.4 | 3.808 | 3.683 | 87.49 | 1.1475<br>1.1877 | 1.403<br>0.71299 | 0.7629 |
| 5.000 | -.07818 | -29.8<br>-5.966 | 8.908<br>0.00 | 59.38 | 1.1877 | 1.2293 | 59.4 | 4.683 | 4.530 | 89.21 | 1.1877<br>1.2293 | 1.501<br>0.66634 | 0.7130 |
| 6.000 | -.06310 | -29.4<br>-4.903 | 9.219<br>0.00 | 61.46 | 1.2293 | 1.2723 | 61.5 | 5.530 | 5.349 | 90.88 | 1.2293<br>1.2723 | 1.606<br>0.62275 | 0.6663 |
| 7.000 | -.05206 | -28.9<br>-4.125 | 9.542<br>0.00 | 63.61 | 1.2723 | 1.3168 | 63.6 | 6.349 | 6.142 | 92.49 | 1.2723<br>1.3168 | 1.718<br>0.58201 | 0.6227 |
| 8.000 | -.04359 | -28.2<br>-3.526 | 9.876<br>0.00 | 65.84 | 1.3168 | 1.3629 | 65.8 | 7.142 | 6.908 | 94.05 | 1.3168<br>1.3629 | 1.838<br>0.54393 | 0.5820 |
| 9.000 | -.03687 | -27.4<br>-3.046 | 10.222<br>0.00 | 68.14 | 1.3629 | 1.4106 | 68.1 | 7.908 | 7.649 | 95.56 | 1.3629<br>1.4106 | 1.967<br>0.50835 | 0.5439 |
| 10.000 | -.03138 | -26.5<br>-2.649 | 10.579<br>0.00 | 70.53 | 1.4106 | 1.4600 | 70.5 | 8.649 | 8.366 | 97.02 | 1.4106<br>1.4600 | 2.105<br>0.47509 | 0.5083 |
| 11.000 | -.02680 | -25.4<br>-2.312 | 10.950<br>0.00 | 73.00 | 1.4600 | 1.5111 | 73.0 | 9.366 | 9.060 | 98.43 | 1.4600<br>1.5111 | 2.252<br>0.44401 | 0.4751 |
| 12.000 | -.02292 | -24.2<br>-2.020 | 11.333<br>0.00 | 75.55 | 1.5111 | 1.5640 | 75.6 | 10.060 | 9.731 | 99.79 | 1.5111<br>1.5640 | 2.410<br>0.41496 | 0.4440 |
| 13.000 | -.00998 | -12.4<br>-0.950 | 11.730<br>10.56 | 78.20 | 1.5640 | 1.6187 | 88.8 | 10.731 | 10.380 | 101.11 | 1.5640<br>1.6187 | 2.579<br>0.38782 | 0.4150 |
| 14.000 | -.00230 | -3.2<br>-0.232 | 12.140<br>18.21 | 80.93 | 1.6187 | 1.6753 | 99.1 | 11.380 | 11.008 | 102.39 | 1.6187<br>1.6753 | 2.759<br>0.36245 | 0.3878 |

PAGE 3 PIR1

| TIME | ROR | PROF / PROFYR | STMPC / WOODC | LANDC | MANGC | TAXRC | ASSVC | TIVMAN | TIVTAX | IVTIV | INFAC / INFAC1 | INTFAC / DISFAC | DFDELA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15.000 | 0.00408 | 6.5 | 12.565 | 83.77 | 1.6753 | 1.7340 | 110.2 | 12.008 | 11.615 | 103.62 | 1.6753 | 2.952 | 0.3624 |
| | | 0.435 | 26.39 | | | | | | | | 1.7340 | 0.33873 | |
| 16.000 | 0.00876 | 15.7 | 13.005 | 86.70 | 1.7340 | 1.7947 | 120.5 | 12.615 | 12.202 | 104.82 | 1.7340 | 3.159 | 0.3387 |
| | | 0.981 | 33.81 | | | | | | | | 1.7947 | 0.31657 | |
| 17.000 | 0.01337 | 26.8 | 13.460 | 89.73 | 1.7947 | 1.8575 | 132.8 | 13.202 | 12.770 | 105.97 | 1.7947 | 3.380 | 0.3166 |
| | | 1.578 | 43.07 | | | | | | | | 1.8575 | 0.29586 | |
| 18.000 | 0.01675 | 37.3 | 13.931 | 92.87 | 1.8575 | 1.9225 | 144.4 | 13.770 | 13.320 | 107.09 | 1.8575 | 3.617 | 0.2959 |
| | | 2.074 | 51.55 | | | | | | | | 1.9225 | 0.27651 | |
| 19.000 | 0.01969 | 48.5 | 14.419 | 96.13 | 1.9225 | 1.9898 | 156.7 | 14.320 | 13.852 | 108.17 | 1.9225 | 3.870 | 0.2765 |
| | | 2.553 | 60.56 | | | | | | | | 1.9898 | 0.25842 | |
| 20.000 | 0.02271 | 61.9 | 14.923 | 99.49 | 1.9898 | 2.0594 | 171.1 | 14.852 | 14.366 | 109.22 | 1.9898 | 4.141 | 0.2584 |
| | | 3.095 | 71.63 | | | | | | | | 2.0594 | 0.24151 | |
| 21.000 | 0.02492 | 74.6 | 15.446 | 102.97 | 2.0594 | 2.1315 | 184.8 | 15.366 | 14.863 | 110.23 | 2.0594 | 4.430 | 0.2415 |
| | | 3.553 | 81.86 | | | | | | | | 2.1315 | 0.22571 | |
| 22.000 | 0.02762 | 91.3 | 15.986 | 106.58 | 2.1315 | 2.2061 | 202.5 | 15.863 | 15.344 | 111.21 | 2.1315 | 4.741 | 0.2257 |
| | | 4.149 | 95.92 | | | | | | | | 2.2061 | 0.21095 | |
| 23.000 | 0.02963 | 107.4 | 16.546 | 110.31 | 2.2061 | 2.2833 | 219.5 | 16.344 | 15.810 | 112.15 | 2.2061 | 5.072 | 0.2109 |
| | | 4.668 | 109.20 | | | | | | | | 2.2833 | 0.19715 | |
| 24.000 | 0.03171 | 126.1 | 17.125 | 114.17 | 2.2833 | 2.3632 | 239.2 | 16.810 | 16.260 | 113.07 | 2.2833 | 5.427 | 0.1971 |
| | | 5.255 | 125.01 | | | | | | | | 2.3632 | 0.18425 | |
| 25.000 | 0.03297 | 142.5 | 17.724 | 118.16 | 2.3632 | 2.4460 | 256.4 | 17.260 | 16.695 | 113.96 | 2.3632 | 5.807 | 0.1842 |
| | | 5.698 | 138.25 | | | | | | | | 2.4460 | 0.17220 | |
| 26.000 | 0.03463 | 163.4 | 18.345 | 122.30 | 2.4460 | 2.5316 | 278.2 | 17.695 | 17.116 | 114.81 | 2.4460 | 6.214 | 0.1722 |
| | | 6.285 | 155.93 | | | | | | | | 2.5316 | 0.16093 | |
| 27.000 | 0.03561 | 181.8 | 18.987 | 126.58 | 2.5316 | 2.6202 | 297.5 | 18.116 | 17.524 | 115.64 | 2.5316 | 6.649 | 0.1609 |
| | | 6.734 | 170.88 | | | | | | | | 2.6202 | 0.15040 | |
| 28.000 | 0.03673 | 203.2 | 19.651 | 131.01 | 2.6202 | 2.7119 | 319.7 | 18.524 | 17.918 | 116.44 | 2.6202 | 7.114 | 0.1504 |
| | | 7.258 | 188.65 | | | | | | | | 2.7119 | 0.14056 | |
| 29.000 | 0.03751 | 223.8 | 20.339 | 135.59 | 2.7119 | 2.8068 | 341.0 | 18.918 | 18.299 | 117.22 | 2.7119 | 7.612 | 0.1406 |
| | | 7.717 | 205.42 | | | | | | | | 2.8068 | 0.13137 | |
| 30.000 | 0.03862 | 249.7 | 21.051 | 140.34 | 2.8068 | 2.9050 | 367.7 | 19.299 | 18.668 | 117.97 | 2.8068 | 8.145 | 0.1314 |
| | | 8.324 | 227.35 | | | | | | | | 2.9050 | 0.12277 | |

| TIME | ROR | PROF<br>PROFYR | STMPC<br>WOODC | LANDC | MANGC | TAXRC | ASSVC | TIVMAN | TIVTAX | TVTIV | INFAC<br>INFAC1 | INTFAC<br>DISFAC | DFDELA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31.000 | 0.03943 | 274.9 | 21.788 | 145.25 | 2.9050 | 3.0067 | 393.6 | 19.668 | 19.024 | 118.69 | 2.9050 | 8.715 | 0.1228 |
| | | 8.869 | 248.38 | | | | | | | | 3.0067 | 0.11474 | |
| 32.000 | 0.04034 | 303.8 | 22.550 | 150.34 | 3.0067 | 3.1119 | 423.2 | 20.024 | 19.369 | 119.39 | 3.0067 | 9.325 | 0.1147 |
| | | 9.494 | 272.86 | | | | | | | | 3.1119 | 0.10723 | |
| 33.000 | 0.04082 | 329.6 | 23.340 | 155.60 | 3.1119 | 3.2209 | 449.7 | 20.369 | 19.703 | 120.07 | 3.1119 | 9.978 | 0.1072 |
| | | 9.988 | 294.08 | | | | | | | | 3.2209 | 0.10022 | |
| 34.000 | 0.04142 | 359.2 | 24.156 | 161.04 | 3.2209 | 3.3336 | 479.9 | 20.703 | 20.026 | 120.73 | 3.2209 | 10.677 | 0.1002 |
| | | 10.564 | 318.87 | | | | | | | | 3.3336 | 0.09366 | |
| 35.000 | 0.04168 | 385.3 | 25.002 | 166.68 | 3.3336 | 3.4503 | 506.7 | 21.026 | 20.338 | 121.36 | 3.3336 | 11.424 | 0.0937 |
| | | 11.010 | 340.03 | | | | | | | | 3.4503 | 0.08754 | |
| 36.000 | 0.04191 | 412.8 | 25.877 | 172.51 | 3.4503 | 3.5710 | 534.8 | 21.338 | 20.640 | 121.98 | 3.4503 | 12.224 | 0.0875 |
| | | 11.467 | 362.28 | | | | | | | | 3.5710 | 0.08181 | |
| 37.000 | 0.04239 | 447.0 | 26.783 | 178.55 | 3.5710 | 3.6960 | 569.6 | 21.640 | 20.932 | 122.57 | 3.5710 | 13.079 | 0.0818 |
| | | 12.081 | 391.03 | | | | | | | | 3.6960 | 0.07646 | |
| 38.000 | 0.04271 | 480.2 | 27.720 | 184.80 | 3.6960 | 3.8254 | 603.4 | 21.932 | 21.215 | 123.15 | 3.6960 | 13.995 | 0.0765 |
| | | 12.638 | 418.57 | | | | | | | | 3.8254 | 0.07146 | |
| 39.000 | 0.04311 | 518.0 | 28.690 | 191.27 | 3.8254 | 3.9593 | 641.7 | 22.215 | 21.488 | 123.70 | 3.8254 | 14.974 | 0.0715 |
| | | 13.282 | 450.44 | | | | | | | | 3.9593 | 0.06678 | |
| 40.000 | 0.04337 | 554.8 | 29.694 | 197.96 | 3.9593 | 4.0978 | 679.0 | 22.488 | 21.753 | 124.24 | 3.9593 | 16.023 | 0.0668 |
| | | 13.869 | 481.05 | | | | | | | | 4.0978 | 0.06241 | |
| 41.000 | 0.04350 | 590.3 | 30.734 | 204.89 | 4.0978 | 4.2413 | 715.1 | 22.753 | 22.008 | 124.76 | 4.0978 | 17.144 | 0.0624 |
| | | 14.398 | 510.18 | | | | | | | | 4.2413 | 0.05833 | |
| 42.000 | 0.04373 | 630.7 | 31.809 | 212.06 | 4.2413 | 4.3897 | 756.0 | 23.008 | 22.256 | 125.26 | 4.2413 | 18.344 | 0.0583 |
| | | 15.018 | 543.94 | | | | | | | | 4.3897 | 0.05451 | |
| 43.000 | 0.04384 | 669.9 | 32.923 | 219.49 | 4.3897 | 4.5433 | 795.6 | 23.256 | 22.495 | 125.75 | 4.3897 | 19.628 | 0.0545 |
| | | 15.579 | 576.15 | | | | | | | | 4.5433 | 0.05095 | |
| 44.000 | 0.04403 | 714.3 | 34.075 | 227.17 | 4.5433 | 4.7024 | 840.5 | 23.495 | 22.727 | 126.22 | 4.5433 | 21.002 | 0.0509 |
| | | 16.234 | 613.35 | | | | | | | | 4.7024 | 0.04761 | |
| 45.000 | 0.04421 | 760.9 | 35.268 | 235.12 | 4.7024 | 4.8669 | 887.6 | 23.727 | 22.951 | 126.68 | 4.7024 | 22.473 | 0.0476 |
| | | 16.909 | 652.45 | | | | | | | | 4.8669 | 0.04450 | |
| 46.000 | 0.04429 | 806.1 | 36.502 | 243.35 | 4.8669 | 5.0373 | 933.2 | 23.951 | 23.167 | 127.12 | 4.8669 | 24.046 | 0.0445 |
| | | 17.524 | 689.89 | | | | | | | | 5.0373 | 0.04159 | |

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| TIME | ROR | PROF<br>PROFYR | STMPC<br>WOODC | LANDC | MANGC | TAXRC | ASSVC | TIVMAN | TIVTAX | TVTIV | INFAC<br>INFAC1 | INTFAC<br>DISFAC | OFDELA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 47.000 | 0.04445 | 857.2<br>18.239 | 37.780<br>732.92 | 251.86 | 5.0373 | 5.2136 | 984.8 | 24.167 | 23.377 | 127.54 | 5.0373<br>5.2136 | 25.729<br>0.03887 | 0.0416 |
| 48.000 | 0.04451 | 906.9<br>18.895 | 39.102<br>774.22 | 260.68 | 5.2136 | 5.3961 | 1034.9 | 24.377 | 23.579 | 127.96 | 5.2136<br>5.3961 | 27.530<br>0.03632 | 0.0389 |
| 49.000 | 0.04457 | 959.0<br>19.570 | 40.470<br>817.50 | 269.80 | 5.3961 | 5.5849 | 1087.3 | 24.579 | 23.775 | 128.35 | 5.3961<br>5.5849 | 29.457<br>0.03395 | 0.0363 |
| 50.000 | 0.04470 | 1017.6<br>20.351 | 41.887<br>867.06 | 279.25 | 5.5849 | 5.7804 | 1146.3 | 24.775 | 23.965 | 128.74 | 5.5849<br>5.7804 | 31.519<br>0.03173 | 0.0339 |

# APPENDIX C

## CUTTING SEQUENCE DATA

CUTTING SEQUENCE DATA

First Figure: Rate of Return if Cut in Current Year
Second Figure: Change in Rate of Return if Let Grow for One More Year

| Age | PLANTATION LAND SI 30 | SI 40 | SI 50 | SI 60 | SI 70 | NATURAL REGENERATION SI 30 | SI 40 | SI 50 | SI 60 | SI 70 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -.44444 | -.41667 | -.39216 | -.37037 | -.35088 | -.37500 | -.34884 | -.32609 | -.30612 | -.28846 |
| | +.00410 | +.00529 | +.00642 | +.00748 | +.00849 | +.00635 | +.00772 | +.00899 | +.01015 | +.01123 |
| 1 | -.44034 | -.41138 | -.38574 | -.36289 | -.34239 | -.36865 | -.34112 | -.31710 | -.29597 | -.27723 |
| | +.19179 | +.18271 | +.17413 | +.16630 | +.15907 | +.16779 | +.15813 | +.14943 | +.14158 | +.13448 |
| 2 | -.24855 | -.22867 | -.21161 | -.19659 | -.18332 | -.20086 | -.18299 | -.16767 | -.15439 | -.14275 |
| | +.07795 | +.07297 | +.06874 | +.06490 | +.06146 | +.06571 | +.06106 | +.05706 | +.05355 | +.05043 |
| 3 | -.17060 | -.15570 | -.14287 | -.13169 | -.12186 | -.13515 | -.12193 | -.11061 | -.10084 | -.09232 |
| | +.04225 | +.03935 | +.03684 | +.03462 | +.03266 | +.03504 | +.03246 | +.03020 | +.02823 | +.02652 |
| 4 | -.12835 | -.11635 | -.10603 | -.09707 | -.08920 | -.10011 | -.08947 | -.08041 | -.07261 | -.06580 |
| | +.02659 | +.02470 | +.02305 | +.02162 | +.02035 | +.02193 | +.02023 | +.01877 | +.01752 | +.01642 |
| 5 | -.10176 | -.09165 | -.08298 | -.07545 | -.06885 | -.07818 | -.06924 | -.06164 | -.05509 | -.04938 |
| | +.01836 | +.01700 | +.01584 | +.01483 | +.02481 | +.01508 | +.01388 | +.01287 | +.01199 | +.01284 |
| 6 | -.08340 | -.07465 | -.06714 | -.06062 | -.04404 | -.06310 | -.05536 | -.04877 | -.04310 | -.03654 |
| | +.01347 | +.01247 | +.01161 | +.01086 | +.02604 | +.01104 | +.01016 | +.00940 | +.00876 | +.02134 |
| 7 | -.06993 | -.06218 | -.05553 | -.04976 | -.01800 | -.05206 | -.04520 | -.03937 | -.03434 | -.01520 |
| | +.01036 | +.00958 | +.00890 | +.01603 | +.02743 | +.00847 | +.00778 | +.00720 | +.00804 | +.04023 |
| 8 | -.05957 | -.05260 | -.04663 | -.03373 | .00943 | -.04359 | -.03742 | -.03217 | -.02630 | .02503 |
| | +.00822 | +.00760 | +.01336 | +.02726 | +.02073 | +.00672 | +.00618 | +.00572 | +.01541 | +.02828 |
| 9 | -.05135 | -.04500 | -.03327 | -.00647 | .03016 | -.03687 | -.03124 | -.02645 | -.01089 | .05331 |
| | +.00672 | +.00620 | +.01369 | +.02274 | +.01897 | +.00549 | +.00504 | +.00818 | +.01711 | +.01841 |
| 10 | -.04463 | -.03880 | -.01958 | .01627 | .04913 | -.03138 | -.02620 | -.01830 | .00622 | .07172 |
| | +.00560 | +.00977 | +.01831 | +.01811 | +.01326 | +.00458 | +.00420 | +.01161 | +.02217 | +.00713 |
| 11 | -.03903 | -.02903 | -.00127 | .03438 | .06239 | -.02680 | -.02200 | -.00669 | .02839 | .07885 |
| | +.00714 | +.01286 | +.01427 | +.01318 | +.01010 | +.00388 | +.01092 | +.01556 | +.01175 | +.00232 |
| 12 | -.03189 | -.01617 | .01300 | .04756 | .07249 | -.02292 | -.01108 | .00887 | .04014 | .08117 |
| | +.01020 | +.01026 | .01078 | +.00978 | +.00902 | +.01294 | +.01053 | +.01295 | +.00737 | +.00042 |
| 13 | -.02169 | -.00591 | .02378 | .05734 | .08151 | -.00998 | -.00055 | .02182 | .04751 | .08159 |
| | +.00842 | +.00897 | +.00739 | +.00567 | +.00516 | +.00768 | +.01058 | +.00722 | +.00450 | -.00012 |
| 14 | -.01327 | .00306 | .03117 | .06301 | .08667 | -.00230 | .01003 | .02904 | .05201 | .08147 |
| | +.00779 | +.00728 | +.00583 | +.00348 | +.00251 | +.00638 | +.00716 | +.00529 | +.00318 | -.00026 |
| 15 | -.00548 | .01034 | .03700 | .06649 | .08918 | .00408 | .01719 | .03433 | .05519 | .08121 |
| | +.00716 | +.00748 | +.00465 | +.00263 | +.00107 | +.00468 | +.00479 | +.00308 | +.00164 | -.00115 |
| 16 | .00168 | .01782 | .04165 | .06912 | .09025 | .00876 | .02198 | .03741 | .05683 | .08006 |
| | +.00654 | +.00563 | +.00346 | +.00159 | +.00048 | +.00461 | +.00306 | +.00293 | +.00130 | -.00125 |
| 17 | .00822 | .02345 | .04511 | .07071 | .09073 | .01337 | .02504 | .04034 | .05813 | .07881 |
| | +.00645 | +.00429 | +.00281 | +.00120 | -.00053 | +.00338 | +.00348 | +.00193 | +.00080 | -.00114 |
| 18 | .01467 | .02774 | .04792 | .07191 | .09020 | .01675 | .02852 | .04227 | .05893 | .07767 |
| | +.00535 | +.00359 | +.00208 | +.00057 | -.00072 | +.00294 | +.00257 | +.00225 | +.00063 | -.00106 |
| 19 | .02002 | .03133 | .05000 | .07248 | .08948 | .01969 | .03109 | .04452 | .05956 | .07661 |
| | +.00409 | +.00303 | +.00171 | +.00011 | -.00095 | +.00302 | +.00256 | +.00121 | +.00049 | -.00098 |
| 20 | .02411 | .03436 | .05171 | .07259 | .08853 | .02271 | .03365 | .04573 | .06005 | .07563 |
| | +.00348 | +.00257 | +.00124 | -.00011 | -.00120 | +.00221 | +.00189 | +.00104 | +.00003 | -.00117 |

CUTTING SEQUENCE DATA (Continued)

| Age | PLANTATION LAND SI 30 | PLANTATION LAND SI 40 | PLANTATION LAND SI 50 | PLANTATION LAND SI 60 | PLANTATION LAND SI 70 | NATURAL REGENERATION SI 30 | NATURAL REGENERATION SI 40 | NATURAL REGENERATION SI 50 | NATURAL REGENERATION SI 60 | NATURAL REGENERATION SI 70 |
|---|---|---|---|---|---|---|---|---|---|---|
| 21 | .02759 | .03693 | .05295 | .07248 | .08733 | .02492 | .03554 | .04677 | .06008 | .07446 |
| | +.00298 | +.00196 | +.00086 | -.00028 | -.00130 | +.00270 | +.00135 | +.00111 | +.00015 | -.00120 |
| 22 | .03057 | .03889 | .05381 | .07220 | .08603 | .02762 | .03689 | .04788 | .06023 | .07326 |
| | +.00228 | +.00168 | +.00056 | -.00041 | -.00129 | +.00201 | +.00172 | +.00075 | -.00005 | -.00109 |
| 23 | .03285 | .04057 | .05437 | .07179 | .08474 | .02963 | .03861 | .04863 | .06018 | .07217 |
| | +.00199 | +.00147 | +.00046 | -.00060 | -.00128 | +.00208 | +.00125 | +.00083 | -.00007 | -.00112 |
| 24 | .03484 | .04204 | .05483 | .07119 | .08346 | .03171 | .03986 | .04946 | .06011 | .07105 |
| | +.00174 | +.00127 | +.00025 | -.00059 | -.00126 | +.00126 | +.00133 | +.00072 | -.00036 | -.00093 |
| 25 | .03658 | .04331 | .05508 | .07060 | .08220 | .03297 | .04119 | .05018 | .05975 | .07012 |
| | +.00153 | +.00111 | +.00020 | -.00064 | -.00129 | +.00166 | +.00075 | +.00029 | -.00021 | -.00085 |
| 26 | .03811 | .04442 | .05528 | .06996 | .08091 | .03463 | .04194 | .05047 | .05954 | .06927 |
| | +.00134 | +.00081 | +.00016 | -.00069 | -.00127 | +.00098 | +.00106 | +.00040 | -.00033 | -.00098 |
| 27 | .03945 | .04523 | .05544 | .06927 | .07964 | .03561 | .04300 | .05087 | .05921 | .06829 |
| | +.00101 | +.00072 | +.00013 | -.00072 | -.00124 | +.00112 | +.00075 | +.00035 | -.00020 | -.00091 |
| 28 | .04046 | .04595 | .05557 | .06855 | .07840 | .03673 | .04375 | .05122 | .05901 | .06738 |
| | +.00090 | +.00063 | +.00001 | -.00075 | -.00120 | +.00078 | +.00050 | +.00016 | -.00031 | -.00092 |
| 29 | .04136 | .04658 | .05556 | .06780 | .07720 | .03751 | .04425 | .05138 | .05870 | .06646 |
| | +.00080 | +.00043 | -.00012 | -.00077 | -.00117 | +.00111 | +.00045 | +.00014 | -.00039 | -.00094 |
| 30 | .04216 | .04701 | .05544 | .06703 | .07603 | .03862 | .04470 | .05152 | .05831 | .06552 |
| | +.00058 | +.00026 | -.00012 | -.00079 | -.00115 | +.00081 | +.00040 | .00000 | -.00027 | -.00072 |
| 31 | .04274 | .04727 | .05532 | .06624 | .07488 | .03943 | .04510 | .05152 | .05804 | .06480 |
| | +.00051 | +.00023 | -.00012 | -.00074 | -.00111 | +.00091 | +.00050 | +.00010 | -.00035 | -.00082 |
| 32 | .04325 | .04750 | .05520 | .06550 | .07377 | .04034 | .04560 | .05162 | .05769 | .06398 |
| | +.00034 | +.00020 | -.00013 | -.00074 | -.00109 | +.00048 | +.00032 | -.00002 | -.00033 | -.00069 |
| 33 | .04359 | .04770 | .05507 | .06476 | .07268 | .04082 | .04592 | .05160 | .05736 | .06329 |
| | +.00031 | +.00019 | -.00020 | -.00071 | -.00103 | +.00060 | +.00041 | -.00003 | -.00040 | -.00072 |
| 34 | .04390 | .04789 | .05487 | .06405 | .07165 | .04142 | .04633 | .05157 | .05696 | .06257 |
| | +.00028 | +.00006 | -.00019 | -.00071 | -.00095 | +.00026 | +.00013 | -.00013 | -.00038 | -.00068 |
| 35 | .04418 | .04795 | .05468 | .06334 | .07070 | .04168 | .04646 | .05144 | .05658 | .06189 |
| | +.00025 | +.00005 | -.00026 | -.00067 | -.00094 | +.00023 | +.00012 | -.00003 | -.00027 | -.00057 |
| 36 | .04443 | .04800 | .05442 | .06267 | .06976 | .04191 | .04658 | .05141 | .05631 | .06132 |
| | +.00013 | +.00005 | -.00024 | -.00064 | -.00093 | +.00048 | +.00021 | -.00013 | -.00034 | -.00060 |
| 37 | .04456 | .04805 | .05418 | .06203 | .06883 | .04239 | .04679 | .05128 | .05597 | .06072 |
| | +.00012 | +.00004 | -.00030 | -.00064 | -.00087 | +.00032 | +.00009 | -.00012 | -.00032 | -.00062 |
| 38 | .04468 | .04809 | .05388 | .06139 | .06796 | .04271 | .04688 | .05116 | .05565 | .06010 |
| | +.00010 | -.00005 | -.00035 | -.00066 | -.00086 | +.00040 | +.00018 | -.00003 | -.00037 | -.00059 |
| 39 | .04478 | .04804 | .05353 | .06073 | .06710 | .04311 | .04706 | .05113 | .05528 | .05951 |
| | +.00001 | -.00013 | -.00033 | -.00062 | -.00082 | +.00026 | -.00006 | -.00020 | -.00035 | -.00050 |
| 40 | .04479 | .04791 | .05320 | .06011 | .06628 | .04337 | .04712 | .05093 | .05493 | .05901 |
| | .00000 | -.00012 | -.00031 | -.00059 | -.00077 | +.00013 | -.00015 | -.00011 | -.00027 | -.00053 |
| 41 | .04479 | .04779 | .05289 | .05952 | .06551 | .04350 | .04727 | .05082 | .05466 | .05848 |
| | +.00001 | -.00011 | -.00030 | -.00055 | -.00076 | +.00023 | -.00004 | -.00018 | -.00032 | -.00049 |

# APPENDIX D

# THE FOREST MANAGEMENT MODEL

```
BEGIN
FILE IN GAVCRD (2,10) ;
FILE IN GAVIN 2 "GAVS""TAPE"(2,56,10) ;
FILE OUT GAVOUT 16(2,15) ;
%*************************************************%
%
%         CONCEPT OF THE MODEL
%
%           THIS MODEL SIMULATES THE PULPWOOD
%       FOREST RESOURCES OF A TYPICAL PULP-PRODUCING
%       COMPANY.  THE MODEL DISTINGUISHES BETWEEN
%       PLANTATION AND NATURAL GROWTH LAND AND
%       RECOGNIZES DIFFERENCES IN GROWTH AND YIELD
%       DUE TO SITE INDEX AND AGE OF STAND.
%           SITE INDICES INCLUDED IN THE MODEL ARE
%       30, 40, 50, 60, AND 70.  (25 YEAR BASIS)
%           STAND AGES CONSIDERED ARE 0 THROUGH 41
%       WHERE STUMPAGE 41 YEARS OLD REPRESENTS
%       MATURE WOOD.  THAT IS, WOOD IN THE APPROPRI-
%       ATE SITE INDEX AND STATUS (PLANTATION OR
%       NATURAL) THAT IS 41 YEARS OLD OR GREATER. IT
%       IS ASSUMED THAT ALL STANDS ARE EVEN AGED AND
%       PARAMETERS FOR AGE 41 REPRESENT AVERAGES FOR
%       WOOD IN THE MATURE CATEGORY.
%
%*************************************************%
%
%         DEFINITION OF TIME SUBSCRIPTS
%
%       SUBSCRIPT     DEFINITION
%
%         J..........VALUE AT THE PREVIOUS POINT IN
%                    TIME
%         K..........VALUE AT THE PRESENT POINT IN
%                    TIME
%         L..........VALUE AT THE NEXT POINT IN
%                    TIME
%         JK.........VALUE DURING THE INTERVAL FROM
%                    J TO K
%         KL.........VALUE DURING THE INTERVAL FROM
%                    K TO L
%
%           THE TIME INTERVAL USED IN THE MODEL IS
%       ONE YEAR.  THE MODEL IS RUN FOR A PERIOD OF
%       ONE HUNDRED YEARS.
%
%             NOTE: VALUES DURING AN INTERVAL OF
%                   TIME ARE REFERENCED TO THE
%                   BEGINNING OF THE INTERVAL.
%                   FOR EXAMPLE, A VALUE FOR THE
%                   INTERVAL FROM TIME 5 TO TIME
%                   6 IS SUBSCRIPTED 5.
%
%*************************************************%
%
%         DEFINITION OF VARIABLE SYMBOLS
%
%     LENGTH        TOTAL LENGTH OF THE SIMULATION
%                                         (YEARS)
%
%     DT            INTERVAL BETWEEN COMPUTATIONS
%                                         (YEARS)
```

```
*
*     DEMCON       DEMAND CONSTANT
*                                           (CORDS/YEAR)
*
*     DEMRAM[K]    DEMAND RAMP INCREASE
*                                           (CORDS/YEAR)
*
*     CONCON1      CONTROL CONSTANT ONE
*                                       (DIMENSIONLESS)
*
*     DEMAND[K]    DEMAND FOR PULPWOOD FOR THE NEXT
*                    YEAR AT TIME K
*                                           (CORDS/YEAR)
*
*     AVDEM[K]     AVERAGE DEMAND FOR PULPWOOD AT
*                    TIME K (AVERAGE DEMAND OVER THE
*                    MOST RECENT FIVE YEAR PERIOD)
*                                           (CORDS/YEAR)
*
*     AXNCC[K]     ACRES OF SITE INDEX XO NATURAL
*                    LAND CLEAR CUT AT TIME K  (CUT
*                    DURING THE JK INTERVAL)
*                                                (ACRES)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*
*     AXNSC[K]     ACRES OF SITE INDEX XO NATURAL
*                    LAND SELECTIVE CUT AT TIME K
*                    (CUT DURING THE JK INTERVAL)
*                                                (ACRES)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*
*     AXPCC[K]     ACRES OF SITE INDEX XO PLANTATION
*                    LAND CLEAR CUT AT TIME K  (CUT
*                    DURING THE JK INTERVAL)
*                                                (ACRES)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*
*     AXPSC[K]     ACRES OF SITE INDEX XO PLANTATION
*                    LAND SELECTIVE CUT AT TIME K
*                    (CUT DURING THE JK INTERVAL)
*                                                (ACRES)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*
*     ACLXP[K]     ACRES OF CLEARED LAND OF SITE
*                    INDEX XO TO BE PLANTED IN
*                    PLANTATION STATUS AT SOME TIME
*                    IN THE FUTURE AT TIME K
*                                                (ACRES)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*
*     AXN[K,Z]     ACRES OF LAND OF SITE INDEX XO IN
*                    NATURAL STATUS Z YEARS OLD AT
```

```
*                    TIME K
*                                                (ACRES)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*                             Z IS 0 THROUGH 41
*
*     AXP[K,Z]      ACRES OF LAND OF SITE INDEX XO IN
*                     PLANTATION STATUS Z YEARS OLD
*                     AT TIME K
*                                                (ACRES)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*                             Z IS 0 THROUGH 41
*
*     YXN[Z]        YIELD OF LAND OF SITE INDEX XO IN
*                     NATURAL STATUS Z YEARS OLD
*                                           (CORDS/ACRE)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*                             Z IS 0 THROUGH 41
*
*     YXP[Z]        YIELD OF LAND OF SITE INDEX XO IN
*                     PLANTATION STATUS Z YEARS OLD
*                                           (CORDS/ACRE)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*                             Z IS 0 THROUGH 41
*
*     SCCXN         SELECTIVE CUTTING COEFFICIENT FOR
*                     SITE INDEX XO NATURAL LAND
*                     (PERCENT CUT REFLECTING SELECT-
*                     IVE CUTTING POLICY)
*                                 (PERCENT OF CORDS)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*
*     SCCXP         SELECTIVE CUTTING COEFFICIENT FOR
*                     SITE INDEX XO PLANTATION LAND
*                     (PERCENT CUT REFLECTING SELECT-
*                     IVE CUTTING POLICY)
*                                 (PERCENT OF CORDS)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*
*     PCXNC[K,Z]    POTENTIAL CORDS IF ALL ACRES IN
*                     SITE INDEX XO NATURAL STATUS Z
*                     YEARS OLD WERE CLEAR CUT AT
*                     TIME K
*                                                (CORDS)
*                          WHERE:
*                             XO IS 30, 40, 50, 60,
*                               OR 70
*                             Z IS 0 THROUGH 41
*
*     PCXNS[K,Z]    POTENTIAL CORDS IF ALL ACRES IN
*                     SITE INDEX XO NATURAL STATUS Z
```

```
%                 YEARS OLD WERE SELECTIVE CUT AT
%                 TIME K
%                                           (CORDS)
%                      WHERE:
%                         X0 IS 30, 40, 50, 60,
%                           OR 70
%                         Z IS 0 THROUGH 41
%
%   PCXPC[K,Z]   POTENTIAL CORDS IF ALL ACRES IN
%                 SITE INDEX X0 PLANTATION STATUS
%                 Z YEARS OLD WERE CLEAR CUT AT
%                 TIME K
%                                           (CORDS)
%                      WHERE:
%                         X0 IS 30, 40, 50, 60,
%                           OR 70
%                         Z IS 0 THROUGH 41
%
%   PCXPS[K,Z]   POTENTIAL CORDS IF ALL ACRES IN
%                 SITE INDEX X0 PLANTATION STATUS
%                 Z YEARS OLD WERE SELECTIVE CUT
%                 AT TIME K
%                                           (CORDS)
%                      WHERE:
%                         X0 IS 30, 40, 50, 60,
%                           OR 70
%                         Z IS 0 THROUGH 41
%
%   TCS[K]       TOTAL CORDS ON THE STUMP AT TIME
%                 K (TOTAL CORDS IF ALL ACRES
%                 WERE CLEAR CUT)
%                                           (CORDS)
%
%   PXNLC[K]     PERCENT OF SITE INDEX X0 NATURAL
%                 LAND TO BE HARVESTED IN THE
%                 NEXT TIME INTERVAL (K TO L)
%                 WHICH IS TO BE CLEAR CUT
%                              (PERCENT OF ACRES)
%                      WHERE:
%                         X0 IS 30, 40, 50, 60,
%                           OR 70
%
%   PXNLS[K]     PERCENT OF SITE INDEX X0 NATURAL
%                 LAND TO BE HARVESTED IN THE
%                 NEXT TIME INTERVAL (K TO L)
%                 WHICH IS TO BE SELECTIVE CUT
%                              (PERCENT OF ACRES)
%                      WHERE:
%                         X0 IS 30, 40, 50, 60,
%                           OR 70
%
%   PXPLC[K]     PERCENT OF SITE INDEX X0
%                 PLANTATION LAND TO BE HARVESTED
%                 IN THE NEXT TIME INTERVAL (K TO
%                 L) WHICH IS TO BE CLEAR CUT
%                              (PERCENT OF ACRES)
%                      WHERE:
%                         X0 IS 30, 40, 50, 60,
%                           OR 70
%
%   PXPLS[K]     PERCENT OF SITE INDEX X0
%                 PLANTATION LAND TO BE HARVESTED
```

```
%                   IN THE NEXT TIME INTERVAL (K TO
%                   L) WHICH IS TO BE SELECTIVE CUT
%                                (PERCENT OF ACRES)
%                        WHERE:
%                           X0 IS 30, 40, 50, 60,
%                             OR 70
%
%*********************************************************%
%
%          VARIABLES IN THE CUTTING SEQUENCE
%
%       NOTE: THE CUTTING SEQUENCE CONSISTS OF 301
%             BLOCKS OF LAND ARRANGED IN A UNIQUE
%             SEQUENCE.  EACH BLOCK REPRESENTS
%             ACERAGE IN A PARTICULAR SITE INDEX
%             AND STATUS (NATURAL OR PLANTATION)
%             AND OF A PARTTICULAR AGE. THE
%             SEQUENCE IS BASED ON RATE-OF-RETURN
%             CONSIDERATIONS AND IS DETERMINED BY
%             THE FOREST INVESTMENT MODEL
%
%    A             SUBSCRIPT FOR SEQUENCE
%                        WHERE:
%                           A=1,2,...,301
%
%    SI[A]         SITE INDEX OF LAND IN BLOCK A OF
%                   THE CUTTING SEQUENCE
%                        WHERE:
%                           SI[A] IS 3, 4, 5, 6,
%                             OR 7
%
%    PORN[A]       STATUS OF LAND IN BLOCK A OF THE
%                   CUTTING SEQUENCE
%                        WHERE:
%                           PORN[A]=0 REPRESENTS
%                             NATURAL LAND
%                           PORN[A]=1 REPRESENTS
%                             PLANTATION LAND
%
%    AGE[A]        AGE OF LAND IN BLOCK A OF THE
%                   CUTTING SEQUENCE
%                        WHERE:
%                           AGE[A] IS 0 THROUGH 41
%
%    PCUT[K,A]     POTENTIAL CORDS CUT IF THE ENTIRE
%                   ACERAGE IN THE BLOCK UNDER
%                   CONSIDERATION IS CUT ACCORDING
%                   TO THE CURRENT CUTTING POLICY
%                   AT TIME K
%                                           (CORDS)
%                        WHERE:
%                           A IS 0 THROUGH 301
%
%    CREM[K,A]     CORDS REMAINING TO BE CUT DURING
%                   THE NEXT TIME INTERVAL (K TO L)
%                   IF ALL ACERAGE IN THE BLOCK
%                   UNDER CONSIDERATION IS CUT
%                   ACCORDING TO THE CURRENT
%                   CUTTING POLICY
%                                           (CORDS)
%                        WHERE:
%                           A IS 0 THROUGH 301
```

```
*
*    CCXNSD[K,D]  CORDS TO CUT FROM SITE INDEX XO
*                   NATURAL LAND D YEARS OLD TO
*                   SATISFY THE REMAINING DEMAND
*                   FOR WOOD DURING THE NEXT TIME
*                   INTERVAL (K TO L)
*                                                 (CORDS)
*                         WHERE:
*                            XO IS 30, 40, 50, 60,
*                              OR 70
*                            D IS 0 THROUGH 41
*
*    CCXPSD[K,D]  CORDS TO CUT FROM SITE INDEX XO
*                   PLANTATION LAND D YEARS OLD TO
*                   SATISFY THE REMAINING DEMAND
*                   FOR WOOD DURING THE NEXT TIME
*                   INTERVAL (K TO L)
*                                                 (CORDS)
*                         WHERE:
*                            XO IS 30, 40, 50, 60,
*                              OR 70
*                            D IS 0 THROUGH 41
*
*    CXN[KL,Z]    CLEAR CUTTING RATE FOR SITE INDEX
*                   XO NATURAL LAND Z YEARS OLD FOR
*                   THE NEXT TIME INTERVAL (K TO L)
*                                            (ACRES/YEAR)
*                         WHERE:
*                            XO IS 30, 40, 50, 60,
*                              OR 70
*                            Z IS 0 THROUGH 41
*
*    SXN[KL,Z]    SELECTIVE CUTTING RATE FOR SITE
*                   INDEX XO NATURAL LAND Z YEARS
*                   OLD FOR THE NEXT TIME INTERVAL
*                   (K TO L)
*                                            (ACRES/YEAR)
*                         WHERE:
*                            XO IS 30, 40, 50, 60,
*                              OR 70
*                            Z IS 0 THROUGH 41
*
*    CXP[KL,Z]    CLEAR CUTTING RATE FOR SITE INDEX
*                   XO PLANTATION LAND Z YEARS OLD
*                   FOR THE NEXT TIME INTERVAL
*                   (K TO L)
*                                            (ACRES/YEAR)
*                         WHERE:
*                            XO IS 30, 40, 50, 60,
*                              OR 70
*                            Z IS 0 THROUGH 41
*
*    SXP[KL,Z]    SELECTIVE CUTTING RATE FOR SITE
*                   INDEX XO PLANTATION LAND Z
*                   YEARS OLD FOR THE NEXT TIME
*                   INTERVAL (K TO L)
*                                            (ACRES/YEAR)
*                         WHERE:
*                            XO IS 30, 40, 50, 60,
*                              OR 70
*                            Z IS 0 THROUGH 41
*****************************************************
```

```
%
%     CCUT[K]       CORDS CUT DURING THE NEXT TIME
%                     INTERVAL (K TO L)
%                                              (CORDS)
%
%     ACUT[K]       ACRES CUT DURING THE NEXT TIME
%                     INTERVAL (K TO L)
%                                              (ACRES)
%
%     CPA[K]        CORDS CUT PER ACRE DURING THE
%                     NEXT TIME INTERVAL (K TO L)
%                                         (CORDS/ACRE)
%
%     USD[K]        UNSATISFIED DEMAND DURING THE
%                     NEXT TIME INTERVAL (K TO L)
%                                              (CORDS)
%
%     PRXO[KL]      PLANTING RATE (PLANTATION LAND)
%                     FOR SITE INDEX XO LAND FOR THE
%                     NEXT TIME INTERVAL (K TO L)
%                                         (ACRES/YEAR)
%                           WHERE:
%                               XO IS 30, 40, 50, 60,
%                                 OR 70
%
%     GXN[KL,Z]     GROWTH RATE FOR SITE INDEX XO
%                     NATURAL LAND Z YEARS OLD
%                     FOR THE NEXT TIME INTERVAL
%                     (K TO L)
%                                         (ACRES/YEAR)
%                           WHERE:
%                               XO IS 30, 40, 50, 60,
%                                 OR 70
%                               Z IS 0 THROUGH 41
%
%     GXP[KL,Z]     GROWTH RATE FOR SITE INDEX XO
%                     PLANTATION LAND Z YEARS OLD
%                     FOR THE NEXT TIME INTERVAL
%                     (K TO L)
%                                         (ACRES/YEAR)
%                           WHERE:
%                               XO IS 30, 40, 50, 60,
%                                 OR 70
%                               Z IS 0 THROUGH 41
%***********************************************%
%***********************************************%
%
INTEGER  TIMEX,J,K,L,JK,KL,Z,CONCON1,DT,LENGTH,I ;
REAL  DEMCON,SCC3N,SCC4N,SCC5N,SCC6N,SCC7N,SCC3P,
      SCC4P,SCC5P,SCC6P,SCC7P ;
INTEGER
ARRAY    SI,PORN,AGE[0:301] ;
REAL
ARRAY   DEMRAM,DEMAND,AVDEM,TCS[0:100] ;
REAL
ARRAY   A3NCC,A4NCC,A5NCC,A6NCC,A7NCC[0:100] ;
REAL
ARRAY   A3NSC,A4NSC,A5NSC,A6NSC,A7NSC[0:100] ;
REAL
ARRAY   A3PCC,A4PCC,A5PCC,A6PCC,A7PCC[0:100] ;
REAL
ARRAY   A3PSC,A4PSC,A5PSC,A6PSC,A7PSC[0:100] ;
```

```
REAL
ARRAY   ACL3P,ACL4P,ACL5P,ACL6P,ACL7P[0:100] ;
REAL
ARRAY   A3N,A4N,A5N,A6N,A7N[0:100,0:50] ;
REAL
ARRAY   A3P,A4P,A5P,A6P,A7P[0:100,0:50] ;
REAL
ARRAY   Y3N,Y4N,Y5N,Y6N,Y7N[0:50] ;
REAL
ARRAY   Y3P,Y4P,Y5P,Y6P,Y7P[0:50] ;
REAL
ARRAY   PC3NC,PC4NC,PC5NC,PC6NC,PC7NC[0:100,0:50] ;
REAL
ARRAY   PC3NS,PC4NS,PC5NS,PC6NS,PC7NS[0:100,0:50] ;
REAL
ARRAY   PC3PC,PC4PC,PC5PC,PC6PC,PC7PC[0:100,0:50] ;
REAL
ARRAY   PC3PS,PC4PS,PC5PS,PC6PS,PC7PS[0:100,0:50] ;
REAL
ARRAY   P3NLC,P4NLC,P5NLC,P6NLC,P7NLC[0:100] ;
REAL
ARRAY   P3NLS,P4NLS,P5NLS,P6NLS,P7NLS[0:100] ;
REAL
ARRAY   P3PLC,P4PLC,P5PLC,P6PLC,P7PLC[0:100] ;
REAL
ARRAY   P3PLS,P4PLS,P5PLS,P6PLS,P7PLS[0:100] ;
REAL
ARRAY     PCUT,CREM[0:100,0:30]] ;
REAL
ARRAY     CC3NSD,CC4NSD,CC5NSD,CC6NSD,CC7NSD[0:100,
          0:50] ;
REAL
ARRAY     CC3PSD,CC4PSD,CC5PSD,CC6PSD,CC7PSD[0:100,
          0:50] ;
REAL
ARRAY   C3N,C4N,C5N,C6N,C7N[0:100,0:50] ;
REAL
ARRAY   C3P,C4P,C5P,C6P,C7P[0:100,0:50] ;
REAL
ARRAY   S3N,S4N,S5N,S6N,S7N[0:100,0:50] ;
REAL
ARRAY   S3P,S4P,S5P,S6P,S7P[0:100,0:50] ;
REAL
ARRAY   CCUT,ACUT,CPA,USD[0:100] ;
REAL
ARRAY   PR30,PR40,PR50,PR60,PR70[0:100] ;
REAL
ARRAY   G3N,G4N,G5N,G6N,G7N[0:100,0:50] ;
REAL
ARRAY   G3P,G4P,G5P,G6P,G7P[0:100,0:50] ;
LABEL     YIELDVALUES,DECISIONCRITERIA,ZEROSYSTEM,
          LEVELINITIALIZE,LEVELCOMPUTE,
          AUXILIARYCOMPUTE,DECISIONCOMPUTE,DL1,DL2,
          DL3,DL4,DL5,DL6,RATECOMPUTE,PL1,PL2,PL3,
          PL4,PL5,PL6,GROWTH,WRITEOUTPUT,
          CLOCKCHECK,CLOCKINCREMENT,ENDOFRUN ;
LABEL     FILLARRAY ;
LABEL    L1,L2 ;
DEFINE    ZLOOP = FOR Z := 0 STEP 1 UNTIL 41 DO # ;
DEFINE    BG = BEGIN LABEL DUMMY # ;
%**********************************************%
%**********************************************%
```

```
%
%          PROCEDURES
%
%**************************************************%
%
REAL
PROCEDURE      MAX (A,B) ;
REAL      A,B ;
BEGIN
MAX := IF A GTR B THEN A
       ELSE B ;
END OF MAX ;
%**************************************************%
%
REAL
PROCEDURE      MIN (A,B) ;
REAL      A,B ;
BEGIN
MIN := IF A LSS B THEN A
       ELSE B ;
END OF MIN ;
%**************************************************%
%
REAL
PROCEDURE      LOG (A) ;
REAL      A ;
BEGIN
LOG := IF A GTR 0 THEN LN(A)/2.3025850930
       ELSE 0 ;
END OF LOG ;
%**************************************************%
%
REAL
PROCEDURE      CLIP (H,L,N,C) ;
REAL      H,L,N,C ;
BEGIN
CLIP := IF N LSS C THEN L
        ELSE H ;
END OF CLIP ;
%**************************************************%
%
REAL
PROCEDURE      SAMPLE (P,Q,T,V) ;
VALUE     P,Q ;
REAL      P,Q,T,V ;
BEGIN
IF TIMEX NEQ 0 THEN
BEGIN
  IF TIMEX GEQ T-DT/2 THEN
  BEGIN
  V := P ;
  T := T+Q ;
  END
END
ELSE
T := Q ;
SAMPLE := V ;
END OF SAMPLE ;
%**************************************************%
%
REAL
PROCEDURE      RAMP (P,Q,V) ;
```

```
VALUE     P,Q,V ;
REAL      P,Q,V ;
BEGIN
IF TIMEX GEQ Q+DT/2 THEN
RAMP := P+V
ELSE
RAMP := V ;
END OF RAMP ;
%**************************************************%
%
REAL
PROCEDURE      SWATCH (H,L,N) ;
REAL      H,L,N ;
BEGIN
SWATCH := IF N EQL 0 THEN H
          ELSE L ;
END OF SWATCH ;
%**************************************************%
%
REAL
PROCEDURE      PULSE (P,Q,R,T) ;
VALUE     P,Q,R ;
REAL      P,Q,R,T ;
BEGIN
IF TIMEX NEQ 0 THEN
  IF TIMEX GEQ T-DT/2 THEN
  BEGIN
    PULSE := P ;
    T := T+R
  END
   ELSE
  PULSE := 0
ELSE
IF T := Q NEQ 0 THEN
PULSE := 0
ELSE
PULSE := P ;
END OF PULSE ;
%**************************************************%
%
PROCEDURE      READARRAY (AAA) ;
REAL
ARRAY     AAA[0] ;
BEGIN
INTEGER   I ;
ALPHA     WD ;
REAL      NU ;
FORMAT    F1(X1,A1,X10,F5.1,X63) ;
FOR I := 0 STEP 1 UNTIL 41 DO
BEGIN
  LABEL  L1 ;
  L1 :
  READ(GAVIN,F1,WD,NU) ;
  IF WD NEQ "Y" THEN
  GO TO L1 ;
  AAA[I] := NU ;
END ;
END OF READARRAY ;
%**************************************************%
%
PROCEDURE      READTWOARRAY (BBB) ;
REAL
```

```
ARRAY     BBB[0,0] ;
BEGIN
INTEGER  I ;
ALPHA    WD ;
REAL     NR ;
FORMAT   F5(X1,A1,X10,F8.1,X60) ;
FOR I := 0 STEP 1 UNTIL 41 DO
BEGIN
  LABEL  L2 ;
  L2 :
  READ(GAVIN,F5,WD,NR) ;
  IF WD NEQ "A" THEN
  GO TO L2 ;
  BBB[K,1] := NR ;
END ;
END OF READTWOARRAY ;
%*****************************************************%
%
REAL
PROCEDURE      SUMMATION(I,I1,I2,FUNCTION) ;
INTEGER  I,I1,I2 ;
REAL      FUNCTION ;
BEGIN
INTEGER  A ;
REAL      SUM ;
A := I ;
SUM := 0 ;
FOR I := I1 STEP 1 UNTIL I2 DO
SUM := SUM + FUNCTION ;
SUMMATION := SUM ;
I := A ;
END OF SUMMATION ;
%*****************************************************%
%
PROCEDURE      CUTDECISION (A,B,C,D,E,F,G,H,I,J) ;
REAL      A,B,C,D,E,F,G,H,I,J ;
BEGIN
P3NLC[K] := A ;
P3NLS[K] := 1-A ;
P3PLC[K] := B ;
P3PLS[K] := 1-B ;
P4NLC[K] := C ;
P4NLS[K] := 1-C ;
P4PLC[K] := D ;
P4PLS[K] := 1-D ;
P5NLC[K] := E ;
P5NLS[K] := 1-E ;
P5PLC[K] := F ;
P5PLS[K] := 1-F ;
P6NLC[K] := G ;
P6NLS[K] := 1-G ;
P6PLC[K] := H ;
P6PLS[K] := 1-H ;
P7NLC[K] := I ;
P7NLS[K] := 1-I ;
P7PLC[K] := J ;
P7PLS[K] := 1-J ;
END OF CUTDECISION ;
%*****************************************************%
%
PROCEDURE      CUTRATE(A) ;
INTEGER  A ;
```

```
BEGIN
LABEL    CL3,CL4,CL5,CL6,CL7,EOP ;
SWITCH   SW1 := CL3,CL4,CL5,CL6,CL7 ;
INTEGER  B,C,D ;
%
%        INTERNAL VARIABLE DEFINITIONS
%          A    SUBSCRIPT FOR SEQUENCE (1,...,301)
%          B    SITE INDEX (3,4,5,6,7)
%          C    TYPE LAND (0=NATURAL; 1=PLANTATION)
%          D    AGE OF WOOD (0 THROUGH 41)
%
B := SI[A] ;
C := PORN[A] ;
D := AGE[A] ;
GO TO SW1[B-2] ;
CL3 ;                         % SITE INDEX 30
IF C EQL 0 THEN
BEGIN                         % NATURAL LAND
  IF A3N[K,D] LEQ 0 THEN
  BEGIN
    PCUT[K,A] := 0 ;
    CC3NSD[K,D] := 0 ;
    C3N[KL,D] := 0 ;
    S3N[KL,D] := 0 ;
    CREM[K,A] := CREM[K,A-1] ;
  END
  ELSE
  BEGIN
    PCUT[K,A] := (P3NLC[K]) x (PC3NC[K,D])
               + (P3NLS[K]) x (PC3NS[K,D]) ;
    CREM[K,A] := CREM[K,A-1] - PCUT[K,A] ;
    CC3NSD[K,D] := CLIP(PCUT[K,A],CREM[K,A-1],
                        CREM[K,A],0) ;
    C3N[KL,D] := (CC3NSD[K,D]/PCUT[K,A]) x
                 (P3NLC[K]) x (A3N[K,D]) ;
    S3N[KL,D] := (CC3NSD[K,D]/PCUT[K,A]) x
                 (P3NLS[K]) x (A3N[K,D]) ;
    CREM[K,A] := MAX(CREM[K,A],0) ;
  END
END
ELSE
BEGIN                         % PLANTATION LAND
  IF A3P[K,D] LEQ 0 THEN
  BEGIN
    PCUT[K,A] := 0 ;
    CC3PSD[K,D] := 0 ;
    C3P[KL,D] := 0 ;
    S3P[KL,D] := 0 ;
    CREM[K,A] := CREM[K,A-1] ;
  END
  ELSE
  BEGIN
    PCUT[K,A] := (P3PLC[K]) x (PC3PC[K,D])
               + (P3PLS[K]) x (PC3PS[K,D]) ;
    CREM[K,A] := CREM[K,A-1] - PCUT[K,A] ;
    CC3PSD[K,D] := CLIP(PCUT[K,A],CREM[K,A-1],
                        CREM[K,A],0) ;
    C3P[KL,D] := (CC3PSD[K,D]/PCUT[K,A]) x
                 (P3PLC[K]) x (A3P[K,D]) ;
    S3P[KL,D] := (CC3PSD[K,D]/PCUT[K,A]) x
                 (P3PLS[K]) x (A3P[K,D]) ;
    CREM[K,A] := MAX(CREM[K,A],0) ;
```

```
  END
END ;
GO TO END ;
CL4 ;                        % SITE INDEX 40
IF C EQL 0 THEN
BEGIN                        % NATURAL LAND
  IF A4N[K,D] LEQ 0 THEN
  BEGIN
    PCUT[K,A] := 0 ;
    CC4NSD[K,D] := 0 ;
    C4N[KL,D] := 0 ;
    S4N[KL,D] := 0 ;
    CREM[K,A] := CREM[K,A-1] ;
  END
  ELSE
  BEGIN
    PCUT[K,A] := (P4NLC[K]) × (PC4NC[K,D])
               + (P4NLS[K]) × (PC4NS[K,D]) ;
    CREM[K,A] := CREM[K,A-1] - PCUT[K,A] ;
    CC4NSD[K,D] := CLIP(PCUT[K,A],CREM[K,A-1],
                        CREM[K,A],0) ;
    C4N[KL,D] := (CC4NSD[K,D]/PCUT[K,A]) ×
                 (P4NLC[K]) × (A4N[K,D]) ;
    S4N[KL,D] := (CC4NSD[K,D]/PCUT[K,A]) ×
                 (P4NLS[K]) × (A4N[K,D]) ;
    CREM[K,A] := MAX(CREM[K,A],0) ;
  END
END
ELSE
BEGIN                        % PLANTATION LAND
  IF A4P[K,D] LEQ 0 THEN
  BEGIN
    PCUT[K,A] := 0 ;
    CC4PSD[K,D] := 0 ;
    C4P[KL,D] := 0 ;
    S4P[KL,D] := 0 ;
    CREM[K,A] := CREM[K,A-1] ;
  END
  ELSE
  BEGIN
    PCUT[K,A] := (P4PLC[K]) × (PC4PC[K,D])
               + (P4PLS[K]) × (PC4PS[K,D]) ;
    CREM[K,A] := CREM[K,A-1] - PCUT[K,A] ;
    CC4PSD[K,D] := CLIP(PCUT[K,A],CREM[K,A-1],
                        CREM[K,A],0) ;
    C4P[KL,D] := (CC4PSD[K,D]/PCUT[K,A]) ×
                 (P4PLC[K]) × (A4P[K,D]) ;
    S4P[KL,D] := (CC4PSD[K,D]/PCUT[K,A]) ×
                 (P4PLS[K]) × (A4P[K,D]) ;
    CREM[K,A] := MAX(CREM[K,A],0) ;
  END
END ;
GO TO END ;
CL5 :                        % SITE INDEX 50
IF C EQL 0 THEN
BEGIN                        % NATURAL LAND
  IF A5N[K,D] LEQ 0 THEN
  BEGIN
    PCUT[K,A] := 0 ;
    CC5NSD[K,D] := 0 ;
    C5N[KL,D] := 0 ;
    S5N[KL,D] := 0 ;
```

```
        CREM[K,A] := CREM[K,A-1] ;
      END
      ELSE
      BEGIN
        PCUT[K,A] := (P5NLC[K]) × (PC5NC[K,D])
                   + (P5NLS[K]) × (PC5NS[K,D]) ;
        CREM[K,A] := CREM[K,A-1] - PCUT[K,A] ;
        CC5NSD[K,D] := CLIP(PCUT[K,A],CREM[K,A-1],
                             CREM[K,A],0) ;
        C5N[KL,D] := (CC5NSD[K,D]/PCUT[K,A]) ×
                     (P5NLC[K]) × (A5N[K,D]) ;
        S5N[KL,D] := (CC5NSD[K,D]/PCUT[K,A]) ×
                     (P5NLS[K]) × (A5N[K,D]) ;
        CREM[K,A] := MAX(CREM[K,A],0) ;
      END
    END
    ELSE
    BEGIN                         % PLANTATION LAND
      IF A5P[K,D] LEQ 0 THEN
      BEGIN
        PCUT[K,A] := 0 ;
        CC5PSD[K,D] := 0 ;
        C5P[KL,D] := 0 ;
        S5P[KL,D] := 0 ;
        CREM[K,A] := CREM[K,A-1] ;
      END
      ELSE
      BEGIN
        PCUT[K,A] := (P5PLC[K]) × (PC5PC[K,D])
                   + (P5PLS[K]) × (PC5PS[K,D]) ;
        CREM[K,A] := CREM[K,A-1] - PCUT[K,A] ;
        CC5PSD[K,D] := CLIP(PCUT[K,A],CREM[K,A-1],
                             CREM[K,A],0) ;
        C5P[KL,D] := (CC5PSD[K,D]/PCUT[K,A]) ×
                     (P5PLC[K]) × (A5P[K,D]) ;
        S5P[KL,D] := (CC5PSD[K,D]/PCUT[K,A]) ×
                     (P5PLS[K]) × (A5P[K,D]) ;
        CREM[K,A] := MAX(CREM[K,A],0) ;
      END
    END ;
    GO TO ENP ;
    CL6 :                         % SITE INDEX 60
    IF C EQL 0 THEN
    BEGIN                         % NATURAL LAND
      IF A6N[K,D] LEQ 0 THEN
      BEGIN
        PCUT[K,A] := 0 ;
        CC6NSD[K,D] := 0 ;
        C6N[KL,D] := 0 ;
        S6N[KL,D] := 0 ;
        CREM[K,A] := CREM[K,A-1] ;
      END
      ELSE
      BEGIN
        PCUT[K,A] := (P6NLC[K]) × (PC6NC[K,D])
                   + (P6NLS[K]) × (PC6NS[K,D]) ;
        CREM[K,A] := CREM[K,A-1] - PCUT[K,A] ;
        CC6NSD[K,D] := CLIP(PCUT[K,A],CREM[K,A-1],
                             CREM[K,A],0) ;
        C6N[KL,D] := (CC6NSD[K,D]/PCUT[K,A]) ×
                     (P6NLC[K]) × (A6N[K,D]) ;
        S6N[KL,D] := (CC6NSD[K,D]/PCUT[K,A]) ×
```

```
                    (P6NLS[K]) × (A6N[K,D]) ;
     CREM[K,A] := MAX(CREM[K,A],0) ;
   END
 END
 ELSE
 BEGIN                          % PLANTATION LAND
   IF A6P[K,D] LEQ 0 THEN
   BEGIN
     PCUT[K,A] := 0 ;
     CC6PSD[K,D] := 0 ;
     C6P[KL,D] := 0 ;
     S6P[KL,D] := 0 ;
     CREM[K,A] := CREM[K,A-1] ;
   END
   ELSE
   BEGIN
     PCUT[K,A] := (P6PLC[K]) × (PC6PC[K,D])
                + (P6PLS[K]) × (PC6PS[K,D]) ;
     CREM[K,A] := CREM[K,A-1] - PCUT[K,A] ;
     CC6PSD[K,D] := CLIP(PCUT[K,A],CREM[K,A-1],
                          CREM[K,A],0) ;
     C6P[KL,D] := (CC6PSD[K,D]/PCUT[K,A]) ×
                  (P6PLC[K]) × (A6P[K,D]) ;
     S6P[KL,D] := (CC6PSD[K,D]/PCUT[K,A]) ×
                  (P6PLS[K]) × (A6P[K,D]) ;
     CREM[K,A] := MAX(CREM[K,A],0) ;
   END
 END ;
 GO TO EOP ;
 CL7 ;                          % SITE INDEX 70
 IF C EQL 0 THEN
 BEGIN                          % NATURAL LAND
   IF A7N[K,D] LEQ 0 THEN
   BEGIN
     PCUT[K,A] := 0 ;
     CC7NSD[K,D] := 0 ;
     C7N[KL,D] := 0 ;
     S7N[KL,D] := 0 ;
     CREM[K,A] := CREM[K,A-1] ;
   END
   ELSE
   BEGIN
     PCUT[K,A] := (P7NLC[K]) × (PC7NC[K,D])
                + (P7NLS[K]) × (PC7NS[K,D]) ;
     CREM[K,A] := CREM[K,A-1] - PCUT[K,A] ;
     CC7NSD[K,D] := CLIP(PCUT[K,A],CREM[K,A-1],
                          CREM[K,A],0) ;
     C7N[KL,D] := (CC7NSD[K,D]/PCUT[K,A]) ×
                  (P7NLC[K]) × (A7N[K,D]) ;
     S7N[KL,D] := (CC7NSD[K,D]/PCUT[K,A]) ×
                  (P7NLS[K]) × (A7N[K,D]) ;
     CREM[K,A] := MAX(CREM[K,A],0) ;
   END
 END
 ELSE
 BEGIN                          % PLANTATION LAND
   IF A7P[K,D] LEQ 0 THEN
   BEGIN
     PCUT[K,A] := 0 ;
     CC7PSD[K,D] := 0 ;
     C7P[KL,D] := 0 ;
     S7P[KL,D] := 0 ;
```

```
    CREM[K,A] := CREM[K,A-1] ;
  END
  ELSE
  BEGIN
    PCUT[K,A] := (P7PLC[K]) × (PC7PC[K,D])
                + (P7PLS[K]) × (PC7PS[K,D]) ;
    CREM[K,A] := CREM[K,A-1] - PCUT[K,A] ;
    CC7PSD[K,D] := CLIP(PCUT[K,A],CREM[K,A-1],
                        CREM[K,A],0) ;
    C7P[KL,D] := (CC7PSD[K,D]/PCUT[K,A]) ×
                 (P7PLC[K]) × (A7P[K,D]) ;
    S7P[KL,D] := (CC7PSD[K,D]/PCUT[K,A]) ×
                 (P7PLS[K]) × (A7P[K,D]) ;
    CREM[K,A] := MAX(CREM[K,A],0) ;
  END
END ;
GO TO EOP ;
EOP ;
END OF CUTRATE ;
%***********************************************%
%
PROCEDURE      PLANTDECISION(A,B,C,D,E) ;
REAL      A,B,C,D,E ;
BEGIN
PR30[KL] := (A) × (ACL3P[K]) ;
PR40[KL] := (B) × (ACL4P[K]) ;
PR50[KL] := (C) × (ACL5P[K]) ;
PR60[KL] := (D) × (ACL6P[K]) ;
PR70[KL] := (E) × (ACL7P[K]) ;
END OF PLANTDECISION ;
%***********************************************%
%
PROCEDURE      TIMING(GAVOUT) ;
FILE GAVOUT ;
BEGIN
REAL      COST ;
ARRAY     T[0:2] ;
FORMAT    TMP1("PROCESS = ",F10.5," SECS.",/,"I/O = ",
                F10.5,"SECS.",/,"RUN TIME = ",F12.5,
                " SECS.",/,"CHARGES =  $",F6.2) ;
T[0] := TIME(2)/60 ;
T[1] := TIME(3)/60 ;
T[2] := T[0] + T[1] ;
COST := ((140/60)×(TIME(2)/3600)) + (140/60) ×
        ((TIME(3)/3600)/3) ;
WRITE(GAVOUT,TMP1,T[0],T[1],T[2],COST) ;
END OF TIMING ;
%***********************************************%
%***********************************************%
%
FORMAT    F2(X4,I1,X5,F10.1,X60) ;
FORMAT    F3(X11,F6.3,X63) ;
FORMAT    F4(X15,F8.1,X57) ;
FORMAT    F10(X10,F10.1,X10,F10.1,X80) ;
FORMAT    F11(X3,I2,X5,10(F5.1,X5),X10) ;
FORMAT    F12(10(X4,F5.3),X30) ;
FORMAT    F13(5(X6,F6.1),X60) ;
FORMAT    F14(X4,I2,10(X3,F8.1),X4) ;
FORMAT    F50(X3,"YR",X4,"Y3N[Z]",X4,"Y4N[Z]",X4,
              "Y5N[Z]",X4,"Y6N[Z]",X4,"Y7N[Z]",X4,
              "Y3P[Z]",X4,"Y4P[Z]",X4,"Y5P[Z]",X4,
              "Y6P[Z]",X4,"Y7P[Z]",X15/) ;
```

```
FORMAT   F51(X10,"SELECTIVE CUTTING COEFFICIENTS",
             X80/) ;
FORMAT   F52(X4,"SCC3N",X4,"SCC4N",X4,"SCC5N",X4,
            "SCC6N",X4,"SCC7N",X4,"SCC3P",X4,
            "SCC4P",X4,"SCC5P",X4,"SCC6P",X4,
            "SCC7P",X30/) ;
FORMAT   F53(X4,"ACL3P[0]",X4,"ACL4P[0]",X4,
            "ACL5P[0]",X4,"ACL6P[0]",X4,"ACL7P[0]",X60) ;
FORMAT   F54(X10,"INITIAL CONDITIONS",X92/) ;
FORMAT   F55(X3,"AGE",X3,"A3N[0,Z]",X3,"A4N[0,Z]",X3,
            "A5N[0,Z]",X3,"A6N[0,Z]",X3,"A7N[0,Z]",X3,
            "A3P[0,Z]",X3,"A4P[0,Z]",X3,"A5P[0,Z]",X3,
            "A6P[0,Z]",X3,"A7P[0,Z]",X4/) ;
FORMAT   F60(X10,"YEARLY DATA",X99//) ;
FORMAT   F61(X3,"YEAR",X4,"DEMAND",X9,"TCS",X6,
             "ACRES CUT (J TO K)",X4,
             "ACRES TO CUT (K TO L)",X41/) ;
FORMAT   F62(X4,I3,X3,F8.1,X3,F11.2,X35,F10.3,X43) ;
FORMAT   F63(X4,I3,X3,F8.1,X3,F11.2,X10,F10.3,X15,F10.3,X43) ;
FORMAT   F70(X10,"CUTTING SEQUENCE",X94/) ;
FORMAT   F71(X10,"SEQUENCE",X5,"SITE INDEX",X5,
            "NAT. OR PLANT.",X5,"AGE",X60/) ;
FORMAT   F72(X13,I3,X12,I1,X16,I1,X12,I2,X60) ;
FORMAT   F73(X3,"J = ",I3,X110) ;
FORMAT   F74(X3,"K = ",I3,X110) ;
FORMAT   F75(X3,"L = ",I3,X110) ;
FORMAT   F76(X3,"JK = ",I3,X109) ;
FORMAT   F77(X3,"KL = ",I3,X109/) ;
FORMAT   F78(X3,"YEAR = ",I3,X107) ;
FORMAT   F79(X3,"DEMRAM = ",F8.1,X100) ;
FORMAT   F80(X3,"DEMAND = ",F8.1,X100) ;
FORMAT   F81(X3,"AVDEM  = ",F8.1,X100/) ;
FORMAT   F82(X3,"TCS = ",F10.2,X101) ;
FORMAT   F83(X3,"ACRES CUT(J TO K) = ",F10.3,X87) ;
FORMAT   F84(X3,"ACRES TO CUT(K TO L) = ",F10.3,
             X87/) ;
FORMAT   F85(X3,"CREM[K,50] = ",F9.2,X3,
             "CREM[K,100] = ",F9.2,X3,"CREM[K,150] = ",
             F9.2,X3,"CREM[K,200] = ",F9.2,X17) ;
FORMAT   F86(X3,"CREM[K,250] = ",F9.2,X3,
             "CREM[K,301] = ",F9.2,X68/) ;
FORMAT   F87(X3,"CORDS CUT(K TO L) = ",F9.2,X88) ;
FORMAT   F88(X3,"CORDS PER ACRE(K TO L) = ",F5.2,
             X87) ;
FORMAT   F89(X3,"UNSATISFIED DEMAND(K TO L) = ",
             F9.2,X79/) ;
FORMAT   F90(X10,"VALUES OF LEVELS",X94/) ;
FORMAT   F91(X20,"ACL3P[K]",X14,"ACL4P[K]",X14,
             "ACL5P[K]",X14,"ACL6P[K]",X14,
             "ACL7P[K]",X4) ;
FORMAT   F92(X20,F8.2,X14,F8.2,X14,F8.2,X14,F8.2,
             X14,F8.2,X4/) ;
FORMAT   F93(X3,"AGE",X3,"A3N[K,Z]",X3,"A3P[K,Z]",
             X3,"A4N[K,Z]",X3,"A4P[K,Z]",X3,
             "A5N[K,Z]",X3,"A5P[K,Z]",X3,
             "A6N[K,Z]",X3,"A6P[K,Z]",X3,
             "A7N[K,Z]",X3,"A7P[K,Z]",X4/) ;
FORMAT   F94(X4,I2,10(X3,F8.2),X4) ;
FORMAT   F95(X10,"CUTTING RATES (ACRES)",X89/) ;
FORMAT   F96("***********************************",
             "***********************************",
             "***********************************",
```

```
            "*********************") ;
FORMAT   F97("*",X4,"*",X11,"SITE INDEX 30",X12,
            "**",X12,"SITE INDEX 40",X12,"**",
            X12,"SITE INDEX 50",X11,"*") ;
FORMAT   F98("*",X4,"*",X5,"NATURAL",X5,"*",X4,
            "PLANTATION",X4,"**",X6,"NATURAL",
            X5,"*",X4,"PLANTATION",X4,"**",X6,
            "NATURAL",X5,"*",X4,"PLANTATION",X3,
            "*") ;
FORMAT   F99("*AGE *  CLEAR * SELECT *   CLEAR *",
            " SELECT **   CLEAR * SELECT *",X3,
            "CLEAR * SELECT **   CLEAR * SELECT",
            " *   CLEAR * SELECT*") ;
FORMAT   F100("*",X4,"*",X8,"*",X8,"*",X9,"*",X8,
            "**",X9,"*",X8,"*",X9,"*",X8,"**",
            X9,"*",X8,"*",X9,"*",X7,"*") ;
FORMAT   F101(X2,I2,X2,2(F7.2,X2,F7.2,X3,F7.2,X2,
            F7.2,X4),F7.2,X2,F7.2,X3,F7.2,X2,
            F7.2,X1) ;
FORMAT   F102("*************************************",
            "*************************************",
            "*******",X38) ;
FORMAT   F103("*",X4,"*",X11,"SITE INTEX 60",X12,
            "**",X12,"SITE INDEX 70",X12,"*",
            X38) ;
FORMAT   F104("*",X4,"*",X5,"NATURAL",X5,"*",X4,
            "PLANTATION",X4,"**",X6,"NATURAL",
            X5,"*",X4,"PLANTATION",X4,"*",X38) ;
FORMAT   F105("*AGE *  CLEAR * SELECT *   CLEAR",
            " * SELECT **   CLEAR * SELECT *",
            "   CLEAR * SELECT *",X38) ;
FORMAT   F106("*",X4,"*",X8,"*",X8,"*",X9,"*",X8,
            "**",X9,"*",X8,"*",X9,"*",X8,"*",
            X38) ;
FORMAT   F107(X2,I2,X2,2(F7.2,X2,F7.2,X3,F7.2,X2,
            F7.2,X4),X36) ;
%*********************************************%
%
WRITE(GAVOUT[NO1]) ;
%
%*********************************************%
FILLARRAY :
FILL SI[*] WITH 0,7,7,7,7,7,7,7,7,7,7,7,7,7,7,7,
                 7,7,7,7,7,7,7,7,7,7,7,7,7,7,7,
                 7,7,7,7,7,7,7,6,7,6,7,6,6,6,7,
                 6,7,7,6,6,6,7,7,6,6,6,6,6,6,7,
                 7,6,6,7,6,7,6,7,7,7,7,6,6,6,6,
                 6,6,5,6,6,6,5,6,6,6,6,5,6,5,5,
                 6,6,6,6,5,7,5,6,5,6,5,5,5,5,4,
                 5,5,5,5,5,4,5,7,6,4,5,6,4,6,4,
                 5,5,5,5,3,5,5,3,3,6,4,4,4,4,4,
                 4,3,5,6,3,4,5,3,4,3,5,4,6,5,5,
                 4,4,5,4,4,3,4,3,5,3,4,3,3,3,5,
                 3,4,3,3,5,5,3,4,4,7,4,4,5,7,3,
                 3,6,4,4,3,5,6,3,3,4,6,4,5,5,4,
                 4,3,3,6,4,3,5,5,3,3,3,3,5,4,7,
                 4,5,3,3,6,5,5,4,3,4,6,4,3,4,4,
                 3,6,6,3,4,5,4,3,4,5,4,3,3,5,3,
                 3,5,3,7,7,4,4,4,6,3,5,5,3,3,3,
                 4,4,5,6,3,5,6,3,4,4,3,4,6,3,5,
                 3,4,7,5,3,4,6,5,3,3,7,4,5,4,6,
                 5,4,7,6,7,5,6,5,6,7,6,7,7,7,6,
```

```
                  7 ;
FILL POPN[*] WITH 0,1,1,1,1,1,1,0,1,1,1,0,1,0,1,0,
                  0,0,1,1,0,0,1,0,0,1,1,1,0,1,0,
                  0,0,1,1,0,1,0,1,1,1,1,1,1,1,1,
                  1,0,0,1,1,1,0,0,1,1,1,1,1,1,0,
                  0,1,1,0,1,0,1,0,1,0,0,1,0,0,0,
                  0,0,1,0,0,0,1,0,0,0,0,1,0,1,1,
                  1,0,0,0,1,0,1,0,0,0,1,1,0,1,1,
                  0,0,1,1,1,1,0,0,1,1,0,0,1,0,0,
                  0,0,0,0,1,0,1,1,1,0,1,1,1,1,0,
                  0,1,0,1,1,0,1,1,0,0,0,0,0,1,0,
                  0,1,1,1,0,0,1,0,1,1,1,0,0,1,0,
                  1,0,0,1,0,0,0,0,0,0,1,0,1,1,0,
                  0,0,0,0,1,1,1,1,0,1,0,1,0,0,0,
                  0,0,1,0,1,0,0,1,1,0,0,1,0,0,1,
                  1,0,0,0,1,0,1,0,0,1,0,0,1,0,1,
                  1,1,0,0,1,1,0,1,0,0,1,1,0,1,0,
                  0,0,1,0,1,0,1,0,1,0,1,0,0,1,0,
                  1,0,0,0,0,1,1,1,0,1,1,1,0,0,1,
                  0,0,1,0,1,1,1,1,1,1,0,0,0,1,0,
                  1,1,1,1,1,1,0,0,1,1,1,0,1,1,0,
                  0 ;
FILL AGE[*] WITH 0,21,25,22,23,26,24,16,27,28,20,
                 21,29,20,30,15,17,23,31,32,22,
                 18,33,26,19,34,19,35,29,36,24,
                 28,27,37,38,25,39,31,30,40,29,
                 41,28,32,31,18,27,33,30,34,33,
                 26,32,34,35,38,37,36,25,39,37,
                 36,23,40,38,24,35,41,40,17,39,
                 41,22,33,29,34,38,24,38,39,31,
                 36,39,32,26,41,37,40,28,41,37,
                 21,40,35,30,35,14,36,25,39,27,
                 33,34,41,32,39,36,34,31,30,29,
                 40,37,13,20,41,40,23,38,22,41,
                 38,35,33,32,40,30,29,41,39,20,
                 37,36,35,34,39,37,38,31,19,37,
                 35,27,36,34,40,29,40,21,26,28,
                 38,33,25,32,36,41,31,35,24,35,
                 30,39,34,34,25,33,32,37,32,27,
                 26,38,30,33,12,29,29,23,16,36,
                 32,19,31,28,31,22,18,30,33,28,
                 18,27,24,22,27,25,28,29,17,26,
                 30,23,21,28,31,26,27,20,26,15,
                 25,21,29,27,17,19,20,23,24,24,
                 16,24,26,21,23,25,16,15,25,22,
                 19,22,24,20,17,21,23,22,18,23,
                 20,18,22,11,14,19,20,18,15,21,
                 17,16,18,21,19,19,16,15,14,17,
                 16,14,20,17,18,19,17,13,16,15,
                 15,15,13,14,18,16,13,14,17,16,
                 10,14,13,14,12,13,15,12,12,11,
                 12,11,12,11,10,10,09,09,08,10,
                 08 ;
WRITE(GAVOUT[PAGE]) ;
WRITE(GAVOUT,F70) ;
WRITE(GAVOUT,F71) ;
FOR I := 1 STEP 1 UNTIL 301 DO
WRITE(GAVOUT,F72,I,SI[I],POPN[I],AGE[I]) ;
GO TO YIELDVALUES ;
%
%
YIELDVALUES:
```

```
BG ;
READARRAY (Y3N) ;
READARRAY (Y4N) ;
READARRAY (Y5N) ;
READARRAY (Y6N) ;
READARRAY (Y7N) ;
READARRAY (Y3P) ;
READARRAY (Y4P) ;
READARRAY (Y5P) ;
READARRAY (Y6P) ;
READARRAY (Y7P) ;
END ;
WRITE(GAVOUT[PAGE]) ;
WRITE(GAVOUT,F50) ;
FOR Z := 0 STEP 1 UNTIL 41 DO
WRITE(GAVOUT,F11,Z,Y3N[Z],Y4N[Z],Y5N[Z],Y6N[Z],
  Y7N[Z],Y3P[Z],Y4P[Z],Y5P[Z],Y6P[Z],Y7P[Z]) ;
GO TO DECISIONCRITERIA ;
%
%
DECISIONCRITERIA:
BG ;
LENGTH := 100 ;
DT := 1 ;
READ(GAVCRD,F2,CONCON1,DEMCON) ;
READ(GAVCRD,F3,SCC3N) ;
READ(GAVCRD,F3,SCC4N) ;
READ(GAVCRD,F3,SCC5N) ;
READ(GAVCRD,F3,SCC6N) ;
READ(GAVCRD,F3,SCC7N) ;
READ(GAVCRD,F3,SCC3P) ;
READ(GAVCRD,F3,SCC4P) ;
READ(GAVCRD,F3,SCC5P) ;
READ(GAVCRD,F3,SCC6P) ;
READ(GAVCRD,F3,SCC7P) ;
END ;
WRITE(GAVOUT[PAGE]) ;
WRITE(GAVOUT,F51) ;
WRITE(GAVOUT,F52) ;
WRITE(GAVOUT,F12,SCC3N,SCC4N,SCC5N,SCC6N,SCC7N,
       SCC3P,SCC4P,SCC5P,SCC6P,SCC7P) ;
GO TO ZEROSYSTEM ;
%
%
ZEROSYSTEM :
BG ;
TIMEX := 0 ;
J := TIMEX - 1 ;
K := TIMEX ;
L := TIMEX + 1 ;
JK := TIMEX - 1 ;
KL := TIMEX ;
END ;
GO TO LEVELINITIALIZE ;
%
%
LEVELINITIALIZE :
BG ;
DEMRAM[K] := 0.0 ;
DEMAND[K] := 100000.0 ;
READ(GAVIN,F4,ACL3P[K]) ;
READ(GAVIN,F4,ACL4P[K]) ;
```

```
READ(GAVIN,F4,ACL5P[K]) ;
READ(GAVIN,F4,ACL6P[K]) ;
READ(GAVIN,F4,ACL7P[K]) ;
READTWOARRAY (A3N) ;
READTWOARRAY (A4N) ;
READTWOARRAY (A5N) ;
READTWOARRAY (A6N) ;
READTWOARRAY (A7N) ;
READTWOARRAY (A3P) ;
READTWOARRAY (A4P) ;
READTWOARRAY (A5P) ;
READTWOARRAY (A6P) ;
READTWOARRAY (A7P) ;
END ;
WRITE(GAVOUT[PAGE]) ;
WRITE(GAVOUT,F53) ;
WRITE(GAVOUT,F13,ACL3P[0],ACL4P[0],ACL5P[0],ACL6P[0],
       ACL7P[0]) ;
WRITE(GAVOUT[PAGE]) ;
WRITE(GAVOUT,F54) ;
WRITE(GAVOUT,F55) ;
FOR Z := 0 STEP 1 UNTIL 41 DO
WRITE(GAVOUT,F14,Z,A3N[0,Z],A4N[0,Z],A5N[0,Z],
       A6N[0,Z],A7N[0,Z],A3P[0,Z],A4P[0,Z],A5P[0,Z],
       A6P[0,Z],A7P[0,Z]) ;
GO TO AUXILIARYCOMPUTE ;
%
%
LEVELCOMPUTE :
BG :
DEMRAM[K] := RAMP(1000,0,DEMRAM[J]) ;
DEMAND[K] := DEMCON + (CONCON1)×(DEMRAM[K]) ;
A3NCC[K] := SUMMATION(Z,0,41,C3N[JK,Z]) ;
A4NCC[K] := SUMMATION(Z,0,41,C4N[JK,Z]) ;
A5NCC[K] := SUMMATION(Z,0,41,C5N[JK,Z]) ;
A6NCC[K] := SUMMATION(Z,0,41,C6N[JK,Z]) ;
A7NCC[K] := SUMMATION(Z,0,41,C7N[JK,Z]) ;
A3NSC[K] := SUMMATION(Z,0,41,S3N[JK,Z]) ;
A4NSC[K] := SUMMATION(Z,0,41,S4N[JK,Z]) ;
A5NSC[K] := SUMMATION(Z,0,41,S5N[JK,Z]) ;
A6NSC[K] := SUMMATION(Z,0,41,S6N[JK,Z]) ;
A7NSC[K] := SUMMATION(Z,0,41,S7N[JK,Z]) ;
A3PCC[K] := SUMMATION(Z,0,41,C3P[JK,Z]) ;
A4PCC[K] := SUMMATION(Z,0,41,C4P[JK,Z]) ;
A5PCC[K] := SUMMATION(Z,0,41,C5P[JK,Z]) ;
A6PCC[K] := SUMMATION(Z,0,41,C6P[JK,Z]) ;
A7PCC[K] := SUMMATION(Z,0,41,C7P[JK,Z]) ;
A3PSC[K] := SUMMATION(Z,0,41,S3P[JK,Z]) ;
A4PSC[K] := SUMMATION(Z,0,41,S4P[JK,Z]) ;
A5PSC[K] := SUMMATION(Z,0,41,S5P[JK,Z]) ;
A6PSC[K] := SUMMATION(Z,0,41,S6P[JK,Z]) ;
A7PSC[K] := SUMMATION(Z,0,41,S7P[JK,Z]) ;
A3N[K,0] := A3PSC[K] + A3NSC[K] ;
A4N[K,0] := A4PSC[K] + A4NSC[K] ;
A5N[K,0] := A5PSC[K] + A5NSC[K] ;
A6N[K,0] := A6PSC[K] + A6NSC[K] ;
A7N[K,0] := A7PSC[K] + A7NSC[K] ;
ACL3P[K] := ACL3P[J] + A3PCC[K] + A3NCC[K]
            - PR30[JK] ;
ACL4P[K] := ACL4P[J] + A4PCC[K] + A4NCC[K]
            - PR40[JK] ;
ACL5P[K] := ACL5P[J] + A5PCC[K] + A5NCC[K]
```

```
PC4PC[K,Z] := (A4P[K,Z]) × (Y4P[Z]) ;
PC5PC[K,Z] := (A5P[K,Z]) × (Y5P[Z]) ;
PC6PC[K,Z] := (A6P[K,Z]) × (Y6P[Z]) ;
PC7PC[K,Z] := (A7P[K,Z]) × (Y7P[Z]) ;
PC3PS[K,Z] := (A3P[K,Z]) × (Y3P[Z]) × (SCC3P) ;
PC4PS[K,Z] := (A4P[K,Z]) × (Y4P[Z]) × (SCC4P) ;
PC5PS[K,Z] := (A5P[K,Z]) × (Y5P[Z]) × (SCC5P) ;
PC6PS[K,Z] := (A6P[K,Z]) × (Y6P[Z]) × (SCC6P) ;
PC7PS[K,Z] := (A7P[K,Z]) × (Y7P[Z]) × (SCC7P) ;
END ;
END ;
GO TO DECISIONCOMPUTE ;
%
%
DECISIONCOMPUTE :
BG :
IF K GEQ 4 THEN
AVDEM[K] := (.20) × (DEMAND[K] + DEMAND[K-1]
            + DEMAND[K-2] + DEMAND[K-3]
            + DEMAND[K-4])
ELSE
IF K EQL 3 THEN
AVDEM[K] := (.25) × (DEMAND[K] + DEMAND[K-1]
            + DEMAND[K-2] + DEMAND[K-3] )
ELSE
IF K EQL 2 THEN
AVDEM[K] := (.3333) × (DEMAND[K] + DEMAND[K-1]
            + DEMAND[K-2])
ELSE
IF K EQL 1 THEN
AVDEM[K] := (.50) × (DEMAND[K] + DEMAND[K-1])
ELSE
IF K EQL 0 THEN
AVDEM[K] := DEMAND[K] ;
TCS[K] := SUMMATION(Z,0,41,PC3NC[K,Z] + PC4NC[K,Z]
          + PC5NC[K,Z] + PC6NC[K,Z] + PC7NC[K,Z]
          + PC3PC[K,Z] + PC4PC[K,Z] + PC5PC[K,Z]
          + PC6PC[K,Z] + PC7PC[K,Z]) ;
END ;
IF TCS[K] GEQ (25) × (AVDEM[K]) THEN GO TO DL1
ELSE
IF TCS[K] GEQ (20) × (AVDEM[K]) THEN GO TO DL2
ELSE
IF TCS[K] GEQ (15) × (AVDEM[K]) THEN GO TO DL3
ELSE
IF TCS[K] GEQ (10) × (AVDEM[K]) THEN GO TO DL4
ELSE
IF TCS[K] GEQ (5)  × (AVDEM[K]) THEN GO TO DL5
ELSE
GO TO DL6 ;
DL1 :
BG ;
CUTDECISION(0.00,0.00,0.00,0.30,0.00,0.40,0.00,
            0.60,0.00,0.70) ;
END ;
GO TO RATECOMPUTE ;
DL2 :
BG ;
CUTDECISION(0.00,0.30,0.05,0.60,0.10,0.60,0.20,
            0.80,0.00,0.90) ;
END ;
GO TO RATECOMPUTE ;
```

```
                 - PR5O[JK] ;
ACL6P[K]  := ACL6P[J] + A6PCC[K] + A6NCC[K]
                 - PR6O[JK] ;
ACL7P[K]  := ACL7P[J] + A7PCC[K] + A7NCC[K]
                 - PR7O[JK] ;
A3P[K,0]  := PR3O[JK] ;
A4P[K,0]  := PR4O[JK] ;
A5P[K,0]  := PR5O[JK] ;
A6P[K,0]  := PR6O[JK] ;
A7P[K,0]  := PR7O[JK] ;
FOR Z := 1 STEP 1 UNTIL 40 DO
BEGIN
A3N[K,Z]  := G3N[JK,Z-1] ;
A4N[K,Z]  := G4N[JK,Z-1] ;
A5N[K,Z]  := G5N[JK,Z-1] ;
A6N[K,Z]  := G6N[JK,Z-1] ;
A7N[K,Z]  := G7N[JK,Z-1] ;
A3P[K,Z]  := G3P[JK,Z-1] ;
A4P[K,Z]  := G4P[JK,Z-1] ;
A5P[K,Z]  := G5P[JK,Z-1] ;
A6P[K,Z]  := G6P[JK,Z-1] ;
A7P[K,Z]  := G7P[JK,Z-1] ;
END ;
A3N[K,41] := A3N[J,41] + G3N[JK,40] - C3N[JK,41]
                 - S3N[JK,41] ;
A4N[K,41] := A4N[J,41] + G4N[JK,40] - C4N[JK,41]
                 - S4N[JK,41] ;
A5N[K,41] := A5N[J,41] + G5N[JK,40] - C5N[JK,41]
                 - S5N[JK,41] ;
A6N[K,41] := A6N[J,41] + G6N[JK,40] - C6N[JK,41]
                 - S6N[JK,41] ;
A7N[K,41] := A7N[J,41] + G7N[JK,40] - C7N[JK,41]
                 - S7N[JK,41] ;
A3P[K,41] := A3P[J,41] + G3P[JK,40] - C3P[JK,41]
                 - S3P[JK,41] ;
A4P[K,41] := A4P[J,41] + G4P[JK,40] - C4P[JK,41]
                 - S4P[JK,41] ;
A5P[K,41] := A5P[J,41] + G5P[JK,40] - C5P[JK,41]
                 - S5P[JK,41] ;
A6P[K,41] := A6P[J,41] + G6P[JK,40] - C6P[JK,41]
                 - S6P[JK,41] ;
A7P[K,41] := A7P[J,41] + G7P[JK,40] - C7P[JK,41]
                 - S7P[JK,41] ;
END ;
GO TO AUXILIARYCOMPUTE ;
%
%
AUXILIARYCOMPUTE :
BG :
FOR Z := 0 STEP 1 UNTIL 41 DO
BEGIN
PC3NC[K,Z] := (A3N[K,Z]) × (Y3N[Z]) ;
PC4NC[K,Z] := (A4N[K,Z]) × (Y4N[Z]) ;
PC5NC[K,Z] := (A5N[K,Z]) × (Y5N[Z]) ;
PC6NC[K,Z] := (A6N[K,Z]) × (Y6N[Z]) ;
PC7NC[K,Z] := (A7N[K,Z]) × (Y7N[Z]) ;
PC3NS[K,Z] := (A3N[K,Z]) × (Y3N[Z]) × (SCC3N) ;
PC4NS[K,Z] := (A4N[K,Z]) × (Y4N[Z]) × (SCC4N) ;
PC5NS[K,Z] := (A5N[K,Z]) × (Y5N[Z]) × (SCC5N) ;
PC6NS[K,Z] := (A6N[K,Z]) × (Y6N[Z]) × (SCC6N) ;
PC7NS[K,Z] := (A7N[K,Z]) × (Y7N[Z]) × (SCC7N) ;
PC3PC[K,Z] := (A3P[K,Z]) × (Y3P[Z]) ;
```

```
DL3 :
BG ;
CUTDECISION(0.10,0.60,0.20,0.70,0.30,0.80,0.40,
            0.90,0.70,1.00) ;
END ;
GO TO RATECOMPUTE ;
DL4 :
BG ;
CUTDECISION(0.10,0.70,0.30,0.70,0.30,0.80,0.90,
            1.00,1.00,1.00) ;
END ;
GO TO RATECOMPUTE ;
DL5 :
BG ;
CUTDECISION(0.25,0.80,0.40,0.90,0.60,1.00,0.90,
            1.00,1.00,1.00) ;
END ;
GO TO RATECOMPUTE ;
DL6 :
BG ;
CUTDECISION(0.50,1.00,0.60,1.00,0.70,1.00,1.00,
            1.00,1.00,1.00) ;
END ;
GO TO RATECOMPUTE ;
%
%
RATECOMPUTE :
BG ;
CREM[K,0] := DEMAND[K] ;
FOR I := 1 STEP 1 UNTIL 301 DO
CUTRATE(I) ;
FOR Z := 0 STEP 1 UNTIL 14 DO
BEGIN
C3N[KL,Z] := 0.0 ;
S3N[KL,Z] := 0.0 ;
END ;
FOR Z := 0 STEP 1 UNTIL 13 DO
BEGIN
C4N[KL,Z] := 0.0 ;
S4N[KL,Z] := 0.0 ;
END ;
FOR Z := 0 STEP 1 UNTIL 11 DO
BEGIN
C5N[KL,Z] := 0.0 ;
S5N[KL,Z] := 0.0 ;
END ;
FOR Z := 0 STEP 1 UNTIL 9 DO
BEGIN
C6N[KL,Z] := 0.0 ;
S6N[KL,Z] := 0.0 ;
END ;
FOR Z := 0 STEP 1 UNTIL 7 DO
BEGIN
C7N[KL,Z] := 0.0 ;
S7N[KL,Z] := 0.0 ;
END ;
FOR Z := 0 STEP 1 UNTIL 15 DO
BEGIN
C3P[KL,Z] := 0.0 ;
S3P[KL,Z] := 0.0 ;
END ;
FOR Z := 0 STEP 1 UNTIL 13 DO
```

```
BEGIN
C4P[KL,Z] := 0.0 ;
S4P[KL,Z] := 0.0 ;
END ;
FOR Z := 0 STEP 1 UNTIL 11 DO
BEGIN
C5P[KL,Z] := 0.0 ;
S5P[KL,Z] := 0.0 ;
END ;
FOR Z := 0 STEP 1 UNTIL 9 DO
BEGIN
C6P[KL,Z] := 0.0 ;
S6P[KL,Z] := 0.0 ;
END ;
FOR Z := 0 STEP 1 UNTIL 7 DO
BEGIN
C7P[KL,Z] := 0.0 ;
S7P[KL,Z] := 0.0 ;
END ;
END ;
CCUT[K] := DEMAND[K] - CREM[K,301] ;
ACUT[K] := SUMMATION(Z,0,41,C3N[KL,Z] + C4N[KL,Z]
           + C5N[KL,Z] + C6N[KL,Z] + C7N[KL,Z] +
           C3P[KL,Z] + C4P[KL,Z] + C5P[KL,Z] +
           C6P[KL,Z] + C7P[KL,Z] + S3N[KL,Z] +
           S4N[KL,Z] + S5N[KL,Z] + S6N[KL,Z] +
           S7N[KL,Z] + S3P[KL,Z] + S4P[KL,Z] +
           S5P[KL,Z] + S6P[KL,Z] + S7P[KL,Z]) ;
CPA[K] := CCUT[K]/ACUT[K] ;
USD[K] := CREM[K,301] ;
IF TCS[K] GEQ (25) x (AVDEM[K]) THEN GO TO PL1
ELSE
IF TCS[K] GEQ (20) x (AVDEM[K]) THEN GO TO PL2
ELSE
IF TCS[K] GEQ (15) x (AVDEM[K]) THEN GO TO PL3
ELSE
IF TCS[K] GEQ (10) x (AVDEM[K]) THEN GO TO PL4
ELSE
IF TCS[K] GEQ (5)  x (AVDEM[K]) THEN GO TO PL5
ELSE
GO TO PL6 ;
PL1 :
BG ;
PLANTDECISION(0.10,0.15,0.20,0.25,0.30) ;
END ;
GO TO GROWTH ;
PL2 :
BG ;
PLANTDECISION(0.30,0.35,0.40,0.45,0.50) ;
END ;
GO TO GROWTH ;
PL3 :
BG ;
PLANTDECISION(0.50,0.55,0.60,0.65,0.70) ;
END ;
GO TO GROWTH ;
PL4 :
BG ;
PLANTDECISION(0.60,0.65,0.70,0.75,0.80) ;
END ;
GO TO GROWTH ;
PL5 :
```

```
BG ;
PLANTDECISION(0.70,0.75,0.80,0.85,0.90) ;
END ;
GO TO GROWTH ;
PL6 ;
BG ;
PLANTDECISION(0.80,0.85,0.90,0.95,1.00) ;
END ;
GO TO GROWTH ;
%
%
GROWTH :
BG ;
FOR Z := 0 STEP 1 UNTIL 40 DO
BEGIN
G3N[KL,Z] := A3N[K,Z] - C3N[KL,Z] - S3N[KL,Z] ;
G4N[KL,Z] := A4N[K,Z] - C4N[KL,Z] - S4N[KL,Z] ;
G5N[KL,Z] := A5N[K,Z] - C5N[KL,Z] - S5N[KL,Z] ;
G6N[KL,Z] := A6N[K,Z] - C6N[KL,Z] - S6N[KL,Z] ;
G7N[KL,Z] := A7N[K,Z] - C7N[KL,Z] - S7N[KL,Z] ;
G3P[KL,Z] := A3P[K,Z] - C3P[KL,Z] - S3P[KL,Z] ;
G4P[KL,Z] := A4P[K,Z] - C4P[KL,Z] - S4P[KL,Z] ;
G5P[KL,Z] := A5P[K,Z] - C5P[KL,Z] - S5P[KL,Z] ;
G6P[KL,Z] := A6P[K,Z] - C6P[KL,Z] - S6P[KL,Z] ;
G7P[KL,Z] := A7P[K,Z] - C7P[KL,Z] - S7P[KL,Z] ;
END ;
END ;
GO TO WRITEOUTPUT ;
%
%
WRITEOUTPUT :
WRITE(GAVOUT[PAGE]) ;
WRITE(GAVOUT,F60) ;
WRITE(GAVOUT,F73,J) ;
WRITE(GAVOUT,F74,K) ;
WRITE(GAVOUT,F75,L) ;
WRITE(GAVOUT,F76,JK) ;
WRITE(GAVOUT,F77,KL) ;
WRITE(GAVOUT,F78,K) ;
WRITE(GAVOUT,F79,DEMRAM[K]) ;
WRITE(GAVOUT,F80,DEMAND[K]) ;
WRITE(GAVOUT,F81,AVDEM[K]) ;
WRITE(GAVOUT,F82,TCS[K]) ;
IF K NEQ 0 THEN
WRITE(GAVOUT,F83,A3PCC[K] + A4PCC[K] + A5PCC[K] +
      A6PCC[K] + A7PCC[K] + A3PSC[K] + A4PSC[K] +
      A5PSC[K] + A6PSC[K] + A7PSC[K] + A3NCC[K] +
      A4NCC[K] + A5NCC[K] + A6NCC[K] + A7NCC[K] +
      A3NSC[K] + A4NSC[K] + A5NSC[K] + A6NSC[K] +
      A7NSC[K] ) ;
WRITE(GAVOUT,F84,ACUT[K]) ;
WRITE(GAVOUT,F87,CCUT[K]) ;
WRITE(GAVOUT,F88,CPA[K]) ;
WRITE(GAVOUT,F89,USD[K]) ;
WRITE(GAVOUT,F85,CREM[K,50],CREM[K,100],
      CREM[K,150],CREM[K,200]) ;
WRITE(GAVOUT,F86,CREM[K,250],CREM[K,301]) ;
WRITE(GAVOUT[PAGE]) ;
WRITE(GAVOUT,F90) ;
WRITE(GAVOUT,F91) ;
WRITE(GAVOUT,F92,ACL3P[K],ACL4P[K],ACL5P[K],
      ACL6P[K],ACL7P[K] ) ;
```

```
WRITE(GAVOUT,F93) ;
FOR Z := 0 STEP 1 UNTIL 41 DO
WRITE(GAVOUT,F94,Z,A3N[K,Z],A3P[K,Z],A4N[K,Z],
       A4P[K,Z],A5N[K,Z],A5P[K,Z],A6N[K,Z],A6P[K,Z],
       A7N[K,Z],A7P[K,Z] ) ;
WRITE(GAVOUT[PAGE]) ;
WRITE(GAVOUT,F95) ;
WRITE(GAVOUT,F96) ;
WRITE(GAVOUT,F97) ;
WRITE(GAVOUT,F98) ;
WRITE(GAVOUT,F99) ;
WRITE(GAVOUT,F100) ;
FOR Z := 0 STEP 1 UNTIL 41 DO
WRITE(GAVOUT,F101,Z,C3N[KL,Z],S3N[KL,Z],C3P[KL,Z],
       S3P[KL,Z],C4N[KL,Z],S4N[KL,Z],C4P[KL,Z],
       S4P[KL,Z],C5N[KL,Z],S5N[KL,Z],C5P[KL,Z],
       S5P[KL,Z]) ;
WRITE(GAVOUT[PAGE]) ;
WRITE(GAVOUT,F95) ;
WRITE(GAVOUT,F102) ;
WRITE(GAVOUT,F103) ;
WRITE(GAVOUT,F104) ;
WRITE(GAVOUT,F105) ;
WRITE(GAVOUT,F106) ;
FOR Z := 0 STEP 1 UNTIL 41 DO
WRITE(GAVOUT,F107,Z,C6N[KL,Z],S6N[KL,Z],C6P[KL,Z],
       S6P[KL,Z],C7N[KL,Z],S7N[KL,Z],C7P[KL,Z],
       S7P[KL,Z]) ;
GO TO CLOCKCHECK ;
%
%
CLOCKCHECK :
IF TIMEX GEQ LENGTH THEN GO TO ENDOFRUN
ELSE GO TO CLOCKINCREMENT ;
%
%
CLOCKINCREMENT :
BG :
TIMEX := TIMEX + DT ;
J := J + 1 ;
K := K + 1 ;
L := L + 1 ;
JK := JK + 1 ;
KL := KL + 1 ;
END ;
GO TO LEVELCOMPUTE ;
%
%
ENDOFRUN :
END.
END;END.          LAST CARD ON OCRDING TAPE
```

# APPENDIX E

# INITIAL CONDITIONS IN THE FOREST MANAGEMENT MODEL

Initial Conditions--Plantation Land (Acres)

| | SITE INDEX | | | | | |
|---|---|---|---|---|---|---|
| AGE | 30 | 40 | 50 | 60 | 70 | TOTAL |
| ACL | 7 | 27 | 78 | 469 | 419 | 1000 |
| 0 | 4 | 18 | 60 | 356 | 298 | 736 |
| 1 | 4 | 19 | 61 | 377 | 299 | 760 |
| 2 | 4 | 19 | 64 | 396 | 300 | 783 |
| 3 | 5 | 20 | 64 | 406 | 304 | 799 |
| 4 | 5 | 20 | 65 | 411 | 308 | 809 |
| 5 | 6 | 20 | 66 | 416 | 310 | 818 |
| 6 | 6 | 20 | 66 | 421 | 310 | 823 |
| 7 | 7 | 20 | 67 | 424 | 313 | 831 |
| 8 | 7 | 21 | 68 | 427 | 313 | 836 |
| 9 | 8 | 21 | 69 | 433 | 315 | 846 |
| 10 | 8 | 21 | 71 | 439 | 321 | 860 |
| 11 | 9 | 22 | 73 | 445 | 325 | 874 |
| 12 | 9 | 22 | 75 | 456 | 330 | 892 |
| 13 | 10 | 22 | 78 | 464 | 336 | 910 |
| 14 | 10 | 23 | 81 | 475 | 339 | 928 |
| 15 | 11 | 23 | 84 | 496 | 341 | 955 |
| 16 | 10 | 24 | 87 | 516 | 350 | 987 |
| 17 | 9 | 26 | 89 | 514 | 357 | 995 |
| 18 | 8 | 27 | 90 | 508 | 360 | 993 |
| 19 | 6 | 28 | 88 | 488 | 369 | 979 |
| 20 | 5 | 28 | 84 | 470 | 375 | 962 |
| 21 | 4 | 26 | 75 | 439 | 385 | 929 |
| 22 | 3 | 25 | 68 | 402 | 389 | 887 |
| 23 | 2 | 24 | 55 | 345 | 388 | 814 |
| 24 | 1 | 22 | 44 | 275 | 375 | 717 |
| 25 | 1 | 20 | 31 | 215 | 360 | 627 |
| 26 | 0 | 18 | 19 | 132 | 340 | 509 |
| 27 | 0 | 16 | 12 | 73 | 318 | 419 |
| 28 | 0 | 12 | 7 | 32 | 279 | 330 |
| 29 | 0 | 8 | 3 | 15 | 205 | 231 |
| 30 | 0 | 6 | 1 | 5 | 110 | 122 |
| 31 | 0 | 4 | 0 | 0 | 32 | 36 |
| 32 | 0 | 3 | 0 | 0 | 0 | 3 |
| 33 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 169 | 675 | 1943 | 11,740 | 10,473 | 25,000 |

Initial Conditions--Natural Land (Acres)

| | SITE INDEX | | | | | |
|---|---|---|---|---|---|---|
| AGE | 30 | 40 | 50 | 60 | 70 | TOTAL |
| 0 | 178 | 401 | 714 | 401 | 89 | 1,783 |
| 1 | 178 | 401 | 714 | 401 | 89 | 1,783 |
| 2 | 178 | 401 | 714 | 401 | 89 | 1,783 |
| 3 | 178 | 401 | 714 | 401 | 89 | 1,783 |
| 4 | 178 | 401 | 714 | 401 | 89 | 1,783 |
| 5 | 178 | 401 | 714 | 401 | 89 | 1,783 |
| 6 | 178 | 401 | 714 | 401 | 89 | 1,783 |
| 7 | 178 | 401 | 714 | 401 | 89 | 1,783 |
| 8 | 178 | 401 | 714 | 401 | 89 | 1,783 |
| 9 | 178 | 402 | 714 | 402 | 89 | 1,785 |
| 10 | 178 | 402 | 714 | 402 | 89 | 1,785 |
| 11 | 178 | 402 | 714 | 402 | 89 | 1,785 |
| 12 | 178 | 402 | 714 | 402 | 89 | 1,785 |
| 13 | 178 | 402 | 714 | 402 | 89 | 1,785 |
| 14 | 178 | 402 | 714 | 402 | 89 | 1,785 |
| 15 | 178 | 402 | 714 | 402 | 89 | 1,785 |
| 16 | 178 | 402 | 714 | 402 | 89 | 1,785 |
| 17 | 178 | 402 | 714 | 402 | 89 | 1,785 |
| 18 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 19 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 20 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 21 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 22 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 23 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 24 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 25 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 26 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 27 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 28 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 29 | 179 | 402 | 714 | 402 | 89 | 1,786 |
| 30 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 31 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 32 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 33 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 34 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 35 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 36 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 37 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 38 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 39 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 40 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| 41 | 179 | 402 | 715 | 402 | 90 | 1,788 |
| Total | 7,500 | 16,875 | 30,000 | 16,875 | 3,750 | 75,000 |

# APPENDIX F

## SAMPLE TABULAR OUTPUT OF THE FOREST MANAGEMENT MODEL

YEARLY DATA

```
J =  55
K =  56
L =  57
JK =  55
KL =  56

YEAR =  56
DEMRAM =  11200.0
DEMAND = 100000.0
AVDEM  = 100000.0

TCS =  895276.90
ACRES CUT(J TO K) =    4204.907
ACRES TO CUT(K TO L) =    4202.847
CORDS CUT(K TO L) = 100000.00
CORDS PER ACRE(K TO L) = 23.79
UNSATISFIED DEMAND(K TO L) =       0.00

CREM[K,50] = 100000.00   CREM[K,100] =  87551.83   CREM[K,150] =        0.00   CREM[K,200] =        0.00
CREM[K,250] =       0.00   CREM[K,301] =       0.00
```

VALUES OF LEVELS

| | | ACL3P[K] 0.00 | | ACL4P[K] 1111.30 | | ACL5P[K] 323.70 | | ACL6P[K] 1649.66 | | ACL7P[K] 343.63 |
|---|---|---|---|---|---|---|---|---|---|---|
| AGE | A3N[K,Z] | A3P[K,Z] | A4N[K,Z] | A4P[K,Z] | A5N[K,Z] | A5P[K,Z] | A6N[K,Z] | A6P[K,Z] | A7N[K,Z] | A7P[K,Z] |
| 0 | 0.00 | 0.00 | 925.97 | 789.34 | 114.24 | 625.72 | 0.40 | 1738.67 | 0.00 | 338.76 |
| 1 | 0.00 | 0.00 | 95.25 | 585.47 | 131.21 | 317.49 | 4.17 | 2215.48 | 0.00 | 333.17 |
| 2 | 0.00 | 0.00 | 41.01 | 153.58 | 114.24 | 620.87 | 2.39 | 2273.59 | 0.00 | 394.68 |
| 3 | 0.00 | 0.00 | 18.12 | 129.12 | 95.58 | 553.16 | 2.54 | 2260.22 | 0.00 | 398.10 |
| 4 | 0.00 | 0.00 | 236.79 | 9.92 | 25.97 | 743.95 | 2.15 | 2256.97 | 0.00 | 400.80 |
| 5 | 0.00 | 0.00 | 8.47 | 0.00 | 204.21 | 674.35 | 0.00 | 2364.08 | 0.00 | 406.52 |
| 6 | 0.00 | 0.01 | 0.00 | 0.00 | 106.52 | 993.61 | 0.00 | 2048.89 | 0.00 | 425.61 |
| 7 | 0.00 | 0.02 | 0.00 | 0.00 | 121.96 | 1662.85 | 0.00 | 1277.06 | 0.00 | 462.03 |
| 8 | 0.00 | 0.06 | 0.00 | 0.00 | 466.17 | 1819.11 | 0.00 | 1153.51 | 0.00 | 411.33 |
| 9 | 0.00 | 0.20 | 0.00 | 0.01 | 627.04 | 2306.46 | 2.67 | 580.02 | 0.00 | 433.66 |
| 10 | 0.03 | 0.34 | 0.00 | 0.01 | 754.98 | 1775.25 | 9.36 | 957.50 | 0.00 | 509.60 |
| 11 | 0.05 | 0.63 | 0.00 | 0.03 | 721.70 | 2238.29 | 0.00 | 126.73 | 0.00 | 774.01 |
| 12 | 0.00 | 2.09 | 0.00 | 1.13 | 720.93 | 1209.78 | 0.00 | 302.03 | 0.00 | 1422.19 |
| 13 | 0.00 | 6.98 | 0.00 | 0.53 | 720.52 | 1125.72 | 0.00 | 330.98 | 0.00 | 1414.88 |
| 14 | 0.00 | 23.27 | 0.00 | 2.02 | 700.72 | 38.87 | 0.00 | 617.53 | 0.00 | 2182.21 |
| 15 | 0.00 | 77.56 | 0.01 | 7.54 | 0.00 | 194.33 | 4.01 | 846.57 | 0.00 | 1856.97 |
| 16 | 133.63 | 153.44 | 0.00 | 31.37 | 0.00 | 562.78 | 4.01 | 1034.84 | 0.00 | 1385.55 |
| 17 | 133.84 | 404.50 | 0.00 | 125.47 | 168.98 | 535.02 | 4.01 | 1636.53 | 0.00 | 329.32 |
| 18 | 1185.34 | 419.21 | 0.03 | 501.15 | 0.08 | 135.56 | 12.03 | 1203.20 | 0.00 | 0.00 |
| 19 | 1667.82 | 93.33 | 595.53 | 790.95 | 0.00 | 85.93 | 8.04 | 1562.54 | 0.00 | 0.00 |
| 20 | 151.68 | 37.58 | 1098.93 | 732.06 | 0.00 | 429.43 | 8.04 | 114.59 | 0.00 | 0.00 |
| 21 | 13.42 | 0.00 | 1334.69 | 208.84 | 285.60 | 431.26 | 0.00 | 0.00 | 0.00 | 0.00 |
| 22 | 0.00 | 0.00 | 358.51 | 13.36 | 285.60 | 436.79 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 | 0.00 | 0.00 | 2.00 | 19.44 | 285.60 | 450.70 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24 | 0.00 | 0.00 | 2.10 | 21.05 | 285.60 | 474.39 | 0.00 | 0.00 | 0.00 | 0.00 |
| 25 | 0.00 | 0.00 | 2.10 | 27.52 | 285.60 | 439.93 | 0.00 | 0.00 | 0.00 | 0.00 |
| 26 | 0.00 | 0.00 | 2.10 | 53.37 | 285.60 | 246.06 | 0.00 | 0.00 | 0.00 | 0.00 |
| 27 | 0.00 | 0.00 | 0.00 | 213.49 | 112.53 | 311.12 | 0.00 | 0.00 | 0.00 | 0.00 |
| 28 | 0.00 | 0.00 | 243.40 | 312.16 | 53.35 | 979.49 | 0.00 | 0.00 | 0.00 | 0.00 |
| 29 | 0.00 | 0.00 | 236.65 | 620.30 | 690.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 30 | 0.00 | 0.00 | 774.26 | 877.68 | 285.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 31 | 0.00 | 0.00 | 1566.42 | 320.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 32 | 0.00 | 0.00 | 590.72 | 42.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 33 | 0.00 | 0.00 | 5.00 | 35.54 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 34 | 0.00 | 0.00 | 2.70 | 69.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 36 | 0.00 | 0.00 | 42.81 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 37 | 0.00 | 0.00 | 1465.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 41 | 3163.98 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

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